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COST AND OPERATIONAL EFFECTIVENESS ANALYSIS FOR SELECTED INTERNATIONAL ICE PATROL MISSION ALTERNATIVES

Robert L. Armacost

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16. Abstract

This report presents the results of a cost and operational effectiveness analysis (COEA) of selected mission alternatives for the International Ice Patrol. The analysis reviewed new technology and management opportunities for improvement and identified selected management, technology, and operational alternatives for which a detailed COEA was conducted. Management alternatives included assigning day-to-day management responsibility for the IIP mission to Canada and to the National Ice Center. Key technology alternatives included a detailed sensitivity analysis of the iceberg drift and deterioration models and development of a risk modeling approach along with data acquisition and data processing improvements. The operations alternatives included surveillance contracted to Canada, surveillance managed through the National Ice Center, and improved radar capabilities for Coast Guard surveillance. The report includes a comprehensive cost analysis of the various alternatives required to meet current performance standards and an analysis of the cost reimbursement system. The report is supported by the following thirteen annexes, each of which is issued as a separate technical report.

- Analysis of Current Operations of the IIP, Annex A of COEA for Selected IIP Mission Alternatives
- Identification of Alternatives for Phase II, Annex B of COEA for Selected IIP Mission Alternatives
- Probability of Detection and Classification Using USCG Surveillance, Annex C of COEA for Selected IIP Mission Alternatives
- Cost Reimbursement for USCG IIP Activities, Annex D of COEA for Selected IIP Mission Alternatives
- Cost Development for USCG IIP Activities, Annex E of COEA for Selected IIP Mission Alternatives
- Evaluation of the Canadian and National Ice Center Management and Surveillance Proposals, Annex F of COEA for Selected IIP Mission Alternatives
- Analysis of the IIP Iceberg Deterioration Model, Annex G of COEA for Selected IIP Mission Alternatives
- Analysis of the IIP Iceberg Drift Model, Annex H of COEA for Selected IIP Mission Alternatives
- Survey of Iceberg Sensing by Satellite Imagery, Annex I of COEA for Selected IIP Mission Alternatives
- Evaluation of Airborne SLAR/FLAR Capability, Annex J of COEA for Selected IIP Mission Alternatives
- Risk Management Model of IIP Operations, Annex K of COEA for Selected IIP Mission Alternatives
- Analysis of IIP Data Processing Requirements, Annex L of COEA for Selected IIP Mission Alternatives
- Review of Sensor Technology and Potential IIP Applications, Annex M of COEA for Selected IIP Mission Alternatives

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METRIC CONVERSION FACTORS

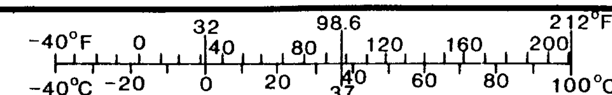
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Mr. Larry Jendro	Ice Operations Division (G-NIO-3)
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EXECUTIVE SUMMARY

The basic mission of the International Ice Patrol (IIP) is to *determine the Limits of All Known Ice along the southeastern, southern, and southwestern edge of the ice region in the vicinity of the Grand Banks of Newfoundland and publish that information in a timely fashion.* The primary products of the IIP are the Ice Bulletins and the Facsimile Ice Chart that depict the Limits of All Known Ice (LAKI) with positional information on selected icebergs and radar targets along with periodic safety broadcasts. Accomplishing the IIP mission involves data and information acquisition, processing, and distribution—finding out where the ice danger is for trans-Atlantic shipping and telling the mariner so as to prevent ship-iceberg collisions. From February 15 through July 1, 1992, vessels of 67 countries carrying over 144 million gross registered tons of cargo passed through the IIP area and benefited from IIP services.

The International Ice Patrol has developed innovative ways to improve its mission effectiveness. Increased international cooperation, communications, technology for detection, and models for predicting iceberg drift and deterioration have been used to improve the quality of information delivered to the mariners to reduce the risk of disaster while reducing the cost of operations. It is realized that new technological developments and/or management approaches may result in increased effectiveness with a potential for decreased costs. The present cost and operational effectiveness analysis reviewed new technology and management opportunities for improvement and conducted a detailed COEA of selected management, technology, and operational alternatives that should provide a foundation for a complete mission analysis by the Program Manager.

The IIP is well managed. The 1995 baseline operating cost for the program, assuming extreme ice years and recovering all administrative costs is approximately $4.5 million, 75% of which is associated with surveillance using Coast Guard HC-130 aircraft. A cost reimbursement mechanism is in place that presently recovers costs from nineteen contributing governments. With the current participating governments, it is expected that 90-95% of all costs will be recovered to the U.S. Treasury.

Management proposals for the day to day management of the IIP were obtained from the Canadian Atmospheric Environment Service Ice Services Branch (ISB) and the U.S. National Ice Center (NIC). Both proposals required comparable staffing and incurred roughly comparable costs in comparison with the present IIP staffing and costs. There were no breakthroughs in staffing levels or costs with the proposals. Both proposals met the management performance requirements specified.

A detailed review of the IIP iceberg deterioration and the iceberg drift models indicated that both models are generally sound. The review revealed an inconsistency between the local wind driven current portion of the drift model and other local wind driven current models. Further analysis is required to resolve the discrepancy. A sensitivity analysis of the models suggested that the estimated position of the detected iceberg is a primary driver as a source of uncertainty in the models. There is no need for more refined environmental data at this time. However, there is a continuing need for better estimates of the Labrador current and the use of drifter buoys should be continued.

The use of the Airborne Tactical Workstation along with Global Positioning System (GPS) navigation input on Coast Guard surveillance patrols will significantly reduce the initial iceberg position error. The rapid development and implementation of this system requires sustained support if Coast Guard surveillance continues.

Although the existing IIP data processing system functions well, equipment failures and the future need to assume full software support, presently provided by Canada (ISB), as well as the potential opportunities to obtain other types of data beyond present processing capabilities, argues in favor of a new data processing system. Immediate support is required for the acquisition and implementation of the Canadian Ice Services Integrated System for IIP.

A comprehensive review of satellite based and other sensor systems revealed that there are no systems in existence or planned that will provide timely information with the spatial resolution needed to replace manned airborne surveillance flights. The Canadian RADARSAT, due for launch in 1995, will provide wide swath coverage of the IIP area, but at a relatively low resolution. It may provide coverage for large icebergs and have some utility at the beginning of the ice season, but airborne surveillance will continue to be required to detect the small and medium icebergs.

The ISB and NIC provided surveillance proposals. The ISB proposal focused on providing area coverage but did not explicitly identify the resulting probability of detection of icebergs. The cost of the Canadian surveillance was approximately $1.9 million. The NIC proposal likewise did not address the POD. The NIC costs for one option were very low, and are believed to be questionable.

The impending technological obsolescence of the AN/APS-135 SLAR radar on the HC-130s has motivated a search for suitable replacement surveillance alternatives. A FY96 Resource Change Proposal provides for replacing the present dry film processor with a digital processor that will extend the service life of the radar to 2010. The digital processor will permit more accurate georegistration of the icebergs and should offer the opportunity for enhanced image analysis. It is expected that the digital processor will also permit a reduction in the search time required to accomplish the same objective. Failure to upgrade the radar incurs considerable cost and performance risk.

There are a number of detailed implementation recommendations in addition to those specified above that support the general findings and conclusions. An important recommendation is the implementation of a risk model developed during the COEA that will help to characterize the risk to the mariner associated with the present IIP operations. The risk analysis, along with the results of this COEA should be used to support a complete Mission Analysis that focuses on a complete customer requirements assessment (initiated during the COEA), refinement of the Mission Measures of Effectiveness, development of mission performance standards, and an assessment of current and planned operations.

SECTION I: COST AND OPERATIONAL EFFECTIVENESS ANALYSIS SUMMARY

1.0 INTRODUCTION

Over the years, the International Ice Patrol (IIP) has developed innovative ways to improve its mission effectiveness. Complementary means of increased international cooperation, communications, technology for detection, and models for predicting iceberg drift and deterioration have been used to improve the quality of information delivered to the mariners to reduce the risk of disaster while reducing the cost of operations. It is realized that new technological developments and/or management approaches may result in increased effectiveness with a potential for decreased costs. The purpose of the cost and operational effectiveness analysis is threefold: (1) identify new technology and management opportunities for improvement, (2) develop at least three feasible alternatives for conducting IIP operations, and (3) perform a cost and operational effectiveness evaluation of the selected feasible alternatives. This COEA should provide a foundation for a complete mission analysis.

The basic mission of the IIP is unchanged since the inception of the ice patrol service. Basic authority for conducting the IIP is provided by SOLAS 74, Chapter V, Regulations 5-8 and 46 USC 738, 783(a)-(d). Under provisions of the SOLAS treaty, the United States is the Managing Government for the IIP. Day to day management responsibility is assigned to the U.S. Coast Guard. Commander, International Ice Patrol, located at Groton, CT operates under the operational control of Commander, Atlantic Area. The IIP mission is to ***determine the Limits of All Known Ice along the southeastern, southern, and southwestern edge of the ice region in the vicinity of the Grand Bands of Newfoundland and publish that information to mariners in a timely fashion***. This mission involves data and information acquisition, processing, and distribution—finding out where the ice danger is for trans-Atlantic shipping and telling the mariner so as to prevent ship-iceberg collisions. The primary products of the IIP are the 0000Z and 1200Z Ice Bulletins and the 1200Z Facsimile Ice Chart that depict the Limits of All Known Ice (LAKI) with positional information on selected icebergs and radar targets and safety bulletins as required. From February 15 to July 1, 1992, vessels from 67 countries carrying over 144 million gross registered tons of cargo passed through the IIP area and benefited from IIP services.

The key data inputs are the iceberg and radar target sightings/reports, and selected environmental data which permits iceberg drift and deterioration to be modeled. The drift and deterioration models and the policies/parameters associated with their operation combine to provide prognosis (predicted) positions of icebergs which determine the LAKI.

The IIP effectively captures available data on iceberg and radar target sightings from several sources. Because of the importance of high quality information along the Limits of All Known Ice, the IIP deploys an Ice Reconnaissance Detachment (ICERECDET) from St. John's, Newfoundland to conduct surveillance flights that concentrate on providing information on icebergs and radar targets in the area defining the LAKI. The primary surveillance device is the AN/APS-135 SLAR augmented with the AN/APS-137 FLAR mounted on an HC-130H aircraft. The AN/APS-135 SLAR radar will have reached technological obsolescence in the 1996 season. Present aircraft assignments effectively limit searches of particular geographic regions to once every two weeks.

A major argument for the reduced frequency of ICERECDET patrols is the availability of all-weather detection capability with the SLAR and the use of the iceberg drift and the iceberg deterioration models. While these models appear to be conceptually sound, they depend heavily on environmental data and iceberg characteristics that may have significant estimation errors. The primary source of environmental data is the U.S. Navy Fleet Numerical Meteorology and Oceanography Center (FNMOC). IIP receives surface wind, wave height, and wave period data twice a day

and sea surface temperature (SST) data once each day. In addition, realtime current data from IIP deployed drift buoys is incorporated on a regular basis to temporarily modify the (geostrophic) Labrador Current data file. The surface wind, iceberg position, estimated iceberg size, and geostrophic current are used in the iceberg drift model. A separate iceberg deterioration model uses the iceberg position, iceberg size, SST, and wave height and period data. Limited experiments to validate the models have been conducted. The results suggested that the models are reasonable representations, but errors are likely associated with input data accuracy.

The IIP operation is well managed. Detailed operational procedures are established and documented. Personnel are well-trained and knowledgeable. The existing computer system greatly facilitates the processing of data. The electronic file interchange procedures in use permit effective quality assurance checks of input data. The major equipment deficiency is the processor speed on the main computer system. The estimated cost of the IIP operation for 1994 that was billed to the contributing governments was $3.6 million. Costs are driven primarily by the ICERECDET which accounts for nearly 75% of the total cost of the IIP.

The critical factor which is well known and confirmed by the present review of IIP operation, is the role of detection. Much of the effort in the IIP has been to compensate for the deficiency in detection by means of models of iceberg drift and deterioration. Primary emphasis in the present analysis is on identifying alternative means of detecting, identifying, and classifying icebergs. Unless that can be done on a continuous basis, some prediction capability will be required. The fundamental question to be addressed is whether there is new technology or procedures that will permit the IIP mission to be accomplished more effectively.

2.0 SUMMARY OF ANALYSIS AND FINDINGS

A hallmark of this study was the close cooperation and support of the Program Manager and the Commander, International Ice Patrol and his staff. Numerous meetings, comments, and suggestions have helped to direct the study in a way that will help the Program Manager.

The initial analysis consisted of a comprehensive review of the literature and the practice of ice detection and observation. A full complement of detection devices and technology was considered, ranging from airborne surveillance and satellite surveillance to ground based radars and unmanned aerial vehicles. The evaluation was restricted to proven technology. Although there are many existing satellite systems, there are few that have the ability to detect icebergs over the IIP area of operations. The Canadian RADARSAT which will be launched in 1995 will have the primary task of monitoring sea ice. It will likely provide some assistance in detecting large icebergs, but it is unlikely that it will provide a reliable source of iceberg detection system. The conclusion is that the primary technology for iceberg detection will remain airborne surveillance.

This conclusion led to the identification of alternatives for the COEA that improved the management of the operation and/or improved the surveillance or reduced the cost of the operation. The alternatives were grouped into three categories: Management, Technology, and Operations. In all cases the present operation of the IIP was used as a baseline for comparing performance and cost. Detailed analyses of the cost development and the cost reimbursement schemes were conducted along with the development of combined probability of detection measures for existing radar systems. These provide the cost and performance measures against which alternatives could be compared.

The Management alternatives included the concept of subcontracting day to day management responsibility for the IIP to Canada and the concept of transferring management responsibility for the

IIP to the National Ice Center. Proposals were solicited and evaluated for feasibility and cost. Both the Canadian Ice Services Branch (ISB) proposal and the National Ice Center (NIC) proposal were responsive. The approximate staffing levels and associated costs were roughly equivalent to present IIP staffing levels and management costs.

The Technology alternatives involved data acquisition on surveillance patrols, data processing at the IIP headquarters, and a review of the drift and deterioration models and development of a risk model for IIP operations. The review of the models confirmed the critical importance of having accurate position information for new sightings, and consequently the need for an effective data acquisition tool. The response is an Airborne Tactical Workstation that is under development by the Commandant at this time. A detailed analytical and empirical sensitivity analysis of the drift and deterioration models also identified the need for good estimates of iceberg size and shape and suggested that the policies regarding assumed iceberg size/shape be reviewed. The analysis indicated that there is no need for improved environmental data. However, there is a continuing need for better estimates of the Labrador current and continued use of drifter buoys is essential. Present and future data processing requirements were reviewed and the analysis supports the IIP recommendation that a new ISIS system be procured for IIP operations. The sensitivity analysis of the drift model identified some inconsistencies between the local wind driven current model and other current models. Finally, the sensitivity analysis provided a foundation for developing a risk modeling approach.

The Operations alternatives focused on surveillance systems and some modeling approaches to improve surveillance effectiveness. Specifically, proposals were obtained from the Canadian Atmospheric Environment Service Ice Services Branch (ISB) and the National Ice Center that would effectively subcontract surveillance. The Canadian proposal was comprehensive, but failed to describe the resultant probability of detection associated with the proposed search strategy. The ISB proposal is cost competitive with the present cost of operation. As part of its total management proposal, NIC also included a provision for surveillance. NIC relies on Canada for air support, but the NIC quoted price is significantly less than that which Canada included in its direct proposal. A detailed review of previous evaluations of the Coast Guard surveillance radars indicated a need for a joint evaluation in order to be able to estimate the actual probabilities of detection. Finally, a planned digital processor upgrade of the existing Coast Guard SLAR radar addresses the technological obsolescence issue and provides a very cost-effective way of enhancing surveillance capability while simultaneously reducing operating costs.

The interrelationships among the alternatives analyzed are illustrated in Figure 1.

3.0 COEA CONCLUSIONS

The COEA is predicated on achieving comparable levels of performance. Both ISB and the NIC have submitted proposals that will provide comparable management performance. With regard to surveillance, the ISB proposed a "locate and identify" search strategy. It is not clear from the ISB proposal whether that search strategy will achieve the present levels of POD. The ISB proposal is very detailed, but additional discussions are necessary to clarify the POD question. The NIC proposal had several questions about search procedures and search effectiveness. There was no demonstration of control over the contracted Canadian and Atlantic Airways aircraft for achieving a particular POD. NIC estimated 600 hours and priced the surveillance at quoted rates. As with ISB, it is not clear that the NIC proposal meets the technical performance requirements. Moreover, it is doubtful that the NIC surveillance cost numbers will hold. The price ISB quoted in their proposal and the price that ISB quoted to NIC are significantly different. NIC's proposal essentially amounts to offering a home to the IIP with the Coast Guard still maintaining primary responsibility. This may be a worthwhile option if the R&D Center relocates in the near future.

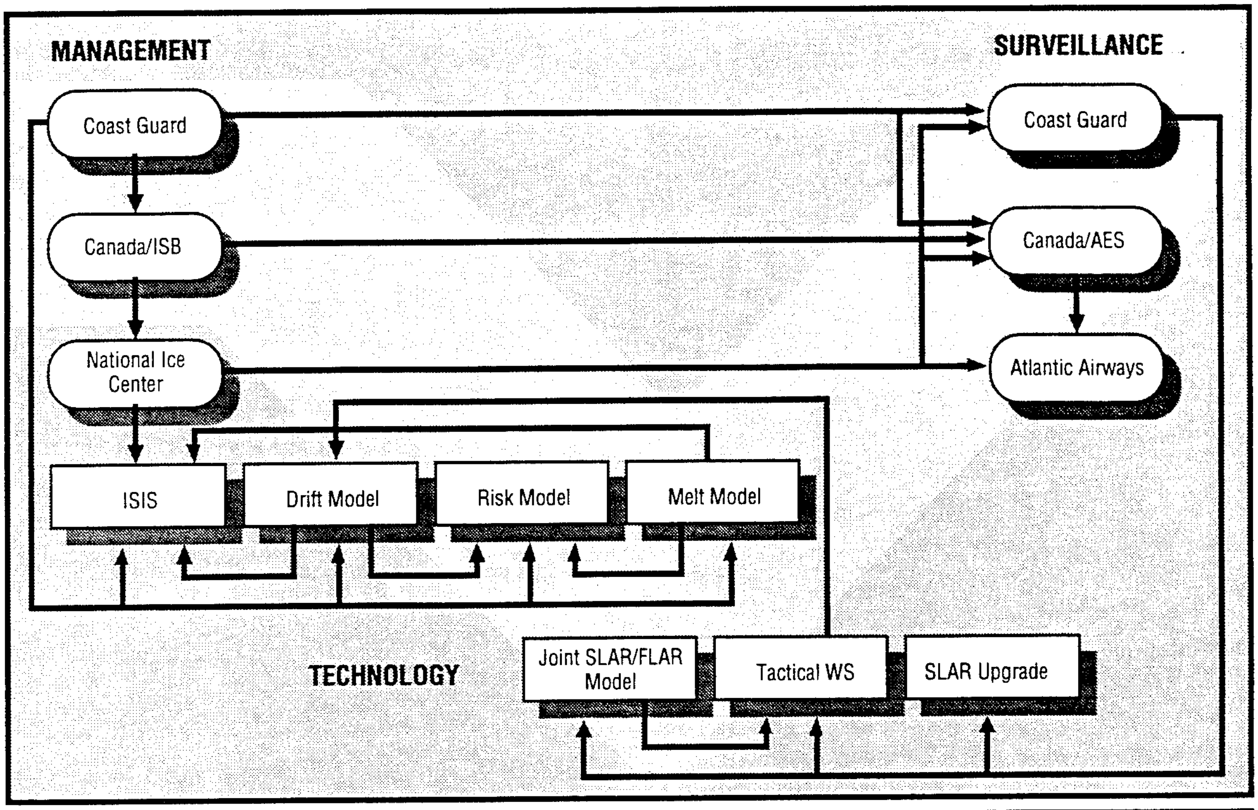

Figure 1: Interrelationships Among COEA Alternatives.

The sensitivity analysis of the drift and deterioration models confirmed the need for accurate position estimates of sighted icebergs and radar targets. The addition of GPS to Coast Guard aircraft and the integration of a Tactical Workstation with an upgraded SLAR and a FLAR radars will significantly reduce the position uncertainty. In addition, the analysis of the drift model suggested that the model for the local wind driven current needs to be revisited to verify its structure or be replaced by a mixed model. If Coast Guard surveillance is continued, the SLAR digital upgrade is a must, paying for itself after 4.5 years by reduced cost of patrol. Similarly, conversion to the ISIS system is a must, providing continued interoperability with Canada and avoiding the development and maintenance of a unique system.

Specific improvements and research requirements are listed in the next three sections.

3.1 OPERATIONS/SURVEILLANCE

- Monitor the evaluation of the ERS-1/IPAP experiment to determine its potential for use with RADARSAT.
- Obtain clarification from ISB on "locate and identify" search strategy and determine probability of detection.
- Develop experiments to assess the search effectiveness of the AN/APS-137 FLAR radar system.
- Develop an algorithmic approach to optimize the search pattern to maximize the probability of detection by taking advantage of surface wind information.
- Develop an interface for the Airborne Tactical Workstation.

- In anticipation of the delivery of the SLAR digital upgrade, develop an experimental plan to evaluate the "new" system and determine appropriate lateral range curves.

- Develop an experimental plan to examine the synergy between the FLAR and the upgraded SLAR, and develop a multi-sensor fusion model to increase the probability of detection and classification of icebergs.

- Explore the possibility of subcontracting a portion of the surveillance at the beginning of the ice season before the iceberg population grows too large or dispersed.

3.2 TECHNOLOGY

- Revisit the Mooney local wind driven current model and verify discrepancies with other models.

- Use historical experimental data where possible to confirm present drift and deterioration model parameters

- Conduct a Monte Carlo simulation evaluation of the system model with interactive resights using the integrated risk analysis model to characterize the propagation of uncertainty through the system.

- Integrate the NPGS stochastic drift model being developed by Dr. Alan Washburn with the simulation model to evaluate the potential for improved estimation of the LAKI.

3.3 OPERATIONS

- Initiate a review with the Department of State to determine what mechanism can be used to credit reimbursements to Coast Guard accounts.

- Using the COEA results, conduct a full Mission Analysis to include: definition of the customer, customer assessment (e.g., present INMARSAT FAX survey); refinement of mission measures of effectiveness and program standards; establishment of mission performance standards, and an assessment of present and planned operations.

- Initiate discussions with the Department of State to explore alternative mechanisms for collecting cost reimbursements directly from the shipper.

- Use the upcoming triennial review of the IIP to develop a plan to increase the number of contributing governments, focusing on those governments with high levels of benefiting tonnage.

- Review cost allocation procedures to ensure that all costs are properly accounted for on a consistent basis and complete costs are submitted for reimbursement.

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SECTION II: DETAILED COST AND OPERATIONAL EFFECTIVENESS ANALYSIS

1.0 OVERVIEW OF THE INTERNATIONAL ICE PATROL

This section provides a brief overview of the International Ice Patrol. Many of the elements contained in this section are described in more detail elsewhere in this report. A detailed description of the current operations of the International Ice Patrol is included in Annex A to this report.

1.1 BACKGROUND AND AUTHORITY

Following the sinking of RMS *Titanic* in 1912, the International Ice Patrol (IIP) was formed to track icebergs and provide warnings to vessels using the trans-Atlantic shipping lanes over the Grand Banks of Newfoundland. Under the provisions of the International Convention for the Safety of Life at Sea (SOLAS), 1974, Chapter V, Regulations 5 through 8, and the provisions of U.S. Code, Title 46, Sections 738, 738a through 738d, the U.S. Coast Guard has been tasked with the management and operation of the IIP. The primary mission of the IIP has not changed over the years. Specifically, the mission of the IIP is to provide a service of observing and disseminating information on ice conditions in the Grand Banks region of the Northwest Atlantic ocean. During the ice season, the southeastern, southern, and southwestern limits of the regions of icebergs in the vicinity of the Grand Banks of Newfoundland are guarded for the purpose of informing passing ships of the extent of this dangerous region. The IIP also studies ice conditions in general, with emphasis on the formation, drift and deterioration of icebergs and assists ships and personnel requiring aid within the limits of operation of the IIP forces.

Large numbers (over 10,000) of icebergs are calved from glaciers on the west coast of Greenland each year. Many are carried south by the Labrador current to the Grand Banks where periods of dense fog occur nearly half of the year. Within its area of responsibility from 40N to 52N latitude and 39W to 57W longitude, the IIP actively tracks icebergs that cross 48N and may be carried into the shipping lanes. Icebergs, fog, and heavy shipping present the ingredients for maritime disaster during the iceberg season extending from March through August. Figure 2 illustrates the IIP area of operation and the bathymetry on the Grand Banks of Newfoundland along with the major branches of the Labrador current that carry the icebergs into the shipping lanes.

Commander, International Ice Patrol (CIIP) is under the operational control of Commander, Coast Guard Atlantic Area. The Program Director for IIP is Chief, Office of Navigation Safety and Waterway

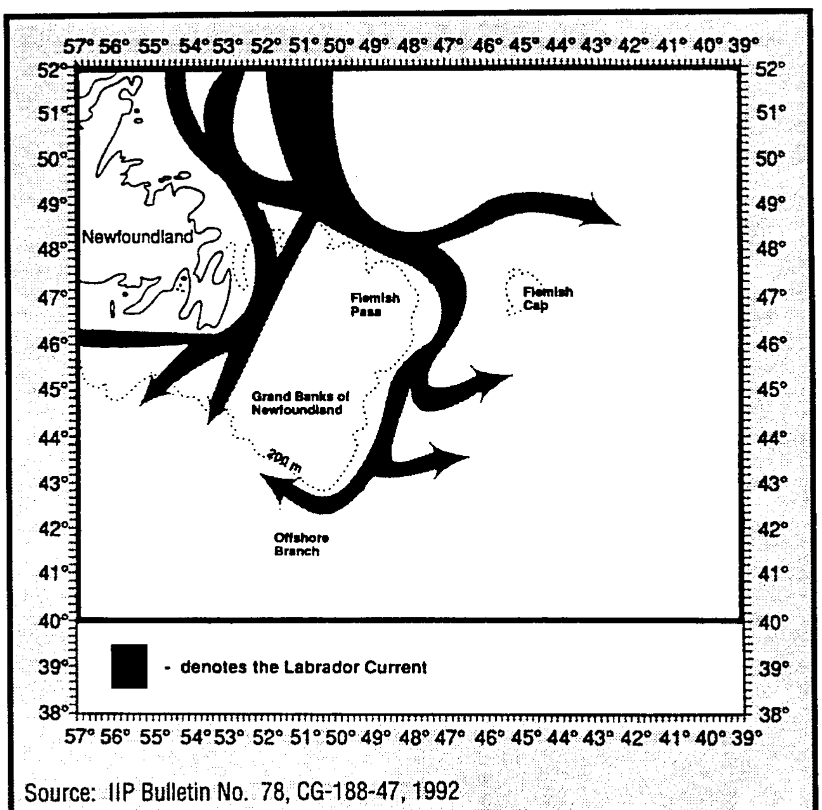

Figure 2: International Ice Patrol Area of Operation.

Services (G-N) in Coast Guard Headquarters with direct management responsibility delegated to Chief, Ice Operations Division (G-NIO) as the Program Manager. Commander, International Ice Patrol directs the IIP from its Operations Center located at the USCG Research and Development Center in Groton, Connecticut. IIP obtains and analyzes iceberg and environmental data, prepares daily ice bulletins and facsimile charts, and responds to requests for ice information. IIP uses aerial ice reconnaissance detachments, passing vessels, observations from other agencies, and, when necessary, surface patrol cutters to survey the southeastern, southern, and southwestern regions of the Grand Banks of Newfoundland for icebergs. IIP's Operations Center uses iceberg drift and deterioration computer models to produce forecasts and charts that are broadcast and distributed by facsimile to warn mariners of the Limits of All Known Ice (LAKI) based on predicted positions of icebergs. The general information flow and the IIP products are illustrated in Figure 3.

1.2 OPERATING ENVIRONMENT

The IIP ice season usually commences in February or March of each year when icebergs begin to exit the sea ice south of 48N latitude and pose a threat to trans-Atlantic shipping. IIP usually conducts one or two aerial reconnaissance flights in January and February to ascertain the sea ice and iceberg conditions to 52N. These flights help to determine season threat and commencement of the ice season. The ice season usually runs to about July or August when CIIP determines that the iceberg threat has receded and the Limits of All Known Ice has generally retreated north of the trans-Atlantic shipping lanes.

One measure of the severity of the ice season is the number of icebergs that pass south of 48N latitude. The IIP defines those years with less than 300 icebergs crossing 48N as light ice years; those with 300-600 crossing 48N as average; those with 600 to 900 crossing 48N as heavy ice years; and

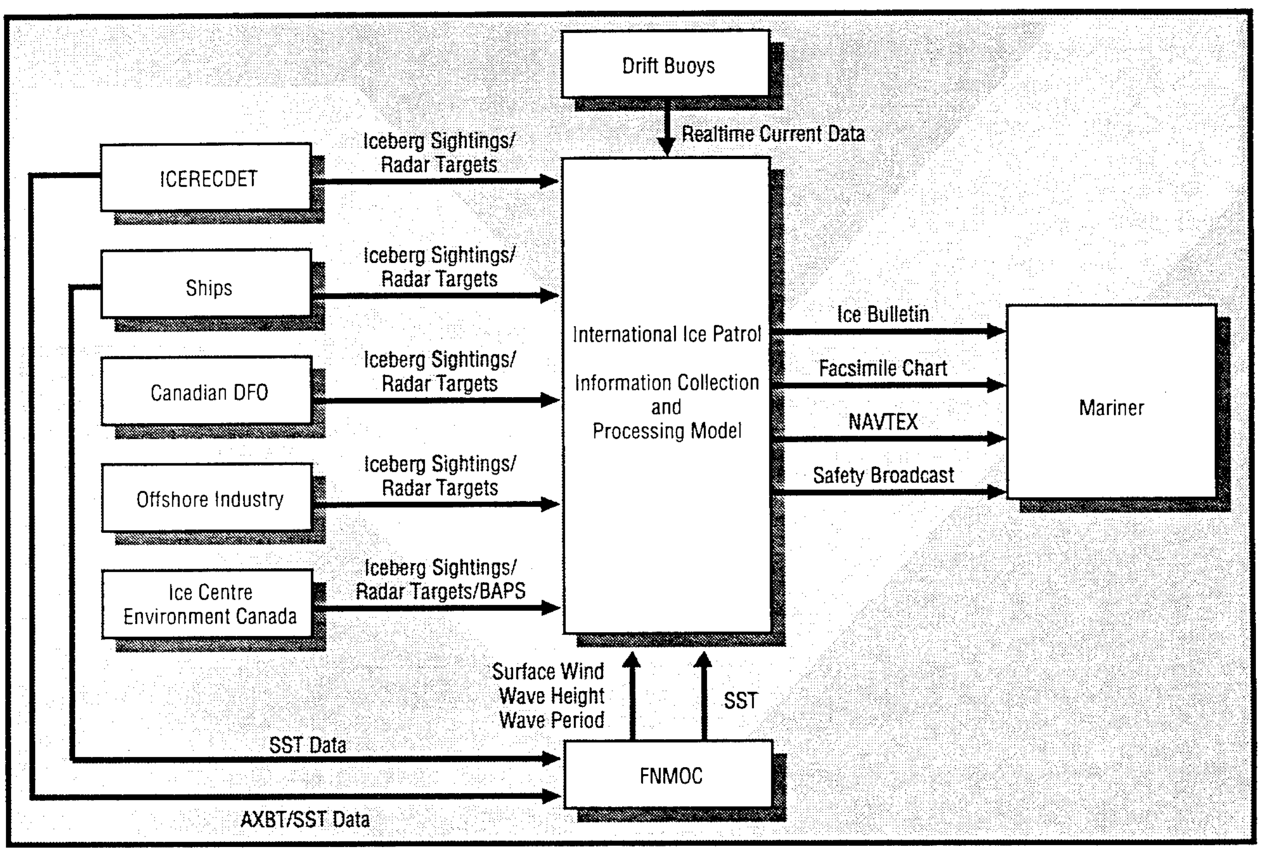

Figure 3: IIP Information Processing Context Diagram.

those with over 900 crossing 48N as extreme. The 1990-1994 seasons have been classified as heavy or extreme with an average of 1,432 icebergs crossing 48N over those five years. These data should be used with caution due to the very different ways the data were collected and recorded over the years. In addition to the severity of the season, changes in operating procedures, technological changes, levels of surveillance effort, changes in reconnaissance techniques, and personnel factors contribute to variability in the estimates.

Significant levels of shipping benefit from IIP services. For example, from February 15 to July 1, 1995, vessels from 67 countries carrying over 144 million gross registered tons of cargo passed through the IIP area of interest.

Over the years, IIP has developed innovative ways to improve its mission effectiveness. Increased international cooperation, improved communications, new technology for detection, and models for predicting iceberg drift and deterioration have been used to improve the quality of information delivered to mariners and reduce the risk of disaster while reducing the cost of operations.

1.3 ICEBERG DETECTION AND IDENTIFICATION

The key element in IIP operations is obtaining information on the location of icebergs. Initially, icebergs were identified visually from ship sightings. Following World War II, aerial visual surveillance was used to increase the coverage and amount of iceberg information. In 1983, the IIP began using airborne Side Looking Airborne Radar (SLAR) augmented with visual surveillance. The combination resulted in increased levels of performance and reduced flight requirements and aircraft deployments..

The IIP receives reports of icebergs and radar targets that may be icebergs from numerous sources. Present sources of iceberg and/or radar targets include: IIP's aerial reconnaissance by its Ice Reconnaissance Detachment (ICERECDET); the Canadian Atmospheric Environmental Service (AES) aerial reconnaissance provided through Ice Centre Environment Canada (ICEC); the Canadian Department of Fisheries and Oceans (DFO) aerial reconnaissance provided by the contracted Atlantic Airways; the National Ice Center (from a variety of DOD sources); ships passing through the ice area; and other miscellaneous sources. ICEC provides IIP with predicted positions of icebergs that have been sighted north of 52N, when they drift south of 52N using their data management system identified as BAPS (iceBerg Analysis and Prediction System). A total of 11 sighting category source codes are used by the IIP.

In recent years, using the aircraft sensor suite, the ICERECDET has deployed to St. John's, Newfoundland for approximately one week approximately every other week. Average reconnaissance revisit to an area is 12 to 14 days. The IIP ICERECDET presently uses HC-130H aircraft equipped with an AN/APS-135 Side Looking Airborne Radar (SLAR) and an AN/APS-137 Forward Looking Airborne Radar (FLAR) from Air Station Elizabeth City and HU-25B aircraft equipped with an AN/APS-131 SLAR from Air Station Cape Cod. Although the HU-25B aircraft is somewhat less expensive to operate, the IIP has found the HC-130H aircraft to be significantly superior operationally because it has much more endurance and effective on scene search time and is a more stable platform. The HU-25 aircraft were recently transferred from Air Station Cape Cod to Air Station Corpus Christi; it is even less likely that they will be available for ICERECDET deployment in the future. In the 1970s, Inertial Navigation Systems provided increased the average initial detection position accuracy to 10 nm. This is expected to be further improved in the near future with installation of GPS navigation systems. (Initial position errors are critical as they are compounded when the berg is exposed to different oceanographic and environmental factors.) During the 1995 season, hand held GPS receivers were being used to update the installed INS system.

1.4 ENVIRONMENTAL DATA AND ICEBERG LOCATION PREDICTION

In order to predict the future positions of icebergs, the IIP uses two computer models to estimate the drift and deterioration of the icebergs. In addition

to the initial position and estimated size of the icebergs, these models depend heavily on various meteorological and oceanographic data such as wind and current velocities, wave heights and periods, and sea surface temperatures obtained from a number of sources such as surface observations by vessels, satellite imagery, and deployed buoys. The majority of these data are provided/ processed by other agencies.

Sea surface temperature (SST), wave height, and wave period data and average wind data are received daily from the U.S. Navy Fleet Numerical Meteorology and Oceanography Center (FNMOC) Monterey via INTERNET to be used in the iceberg deterioration and drift models. The Sea Ice Edge (1/10 coverage) is received daily from ICEC as their FICN2 product and is included on IIP facsimile charts.

The ICERECDETs strategically deploy 8 to 15 satellite tracked ocean drifting buoys each year. These World Ocean Circulation Experiment (WOCE) drifters have surface temperature sensors and a drogue at 50 meters. They cost approximately $3,000.00 and have a life expectancy of 4 to 6 months. The information acquisition costs is $4,000 per buoy year through Service ARGOS. Drifter track current and SST data is received and processed daily. IIP uses the drifter data to update the historical (geostrophic) current data file once per week. Periodically, IIP permanently modifies the historical current data file with the data provided by those drifters deployed since the last permanent update. Drifter data is shared with other interested activities.

Air-deployable eXpendable BathyThermographs (AXBTs), provided by the Canadian Maritime Command/Meteorological and Oceanographic Center (METOC), are deployed by the ICERECDET. The data received from the ICERECDET are forwarded to METOC, the U.S. Naval Atlantic Meteorology and Oceanography Center (NLMOC), and FNMOC for use in their ocean temperature models which support IIP. Sea Surface Temperature reports are also received from transiting ships and Coast Guard patrol/ research vessels and forwarded to FNMOC.

1.5 ICE BULLETINS AND OTHER PRODUCTS

The initial iceberg positional data and the environmental data are used in the iceberg drift and iceberg deterioration models to predict the positions and size of icebergs. These models and the environmental data are discussed in detail in section 3.2. A system of desktop microcomputers and a modified VAX computer-based system developed by INTERGRAPH are used to process the data and execute the models. The critical information for preparing the Ice Bulletin and Facsimile Chart is the estimated position of known icebergs. Using the existing model, the predicted position of each iceberg has a defined error circle depending on the duration of the prediction (up to 30 nm maximum error). New sightings are used to update estimated positions (termed resighting) and reduce the error in estimation. Generally, limit setting icebergs are removed from active status when they have achieved 150% melt, while non limit setting icebergs are removed from the active file after 125% melt. The IIP uses the predicted position of icebergs with associated error circles to determine the Limits of All Known Ice (LAKI). Particular emphasis is given to the southeastern, southern, and southwestern edges of the IIP area of operation. Within the LAKI, the IIP identifies an "area of many icebergs." At no point does the IIP attempt to provide a comprehensive identification of all icebergs within the region nor does it provide any iceberg density estimates to the maritime community.

The primary products of the IIP are the 0000Z and 1200Z Ice Bulletins and the 1200Z Facsimile Chart broadcast at 1600Z and 1810Z. U.S. Coast Guard Communications Station Boston, MA, NMF/NIK, and Canadian Coast Guard Radio Station St. John's, Newfoundland, VON, are the primary radio stations that disseminate the 0000Z and 1200Z Bulletins. Other Bulletin transmitting stations include: METOC Halifax, Nova Scotia/CFH; Canadian Coast Guard Radio Station Halifax/VCS; Radio Station Bracknel, UK/GFE; U.S. Navy LCMP Broadcast Stations Norfolk/NAM and Key West; and the INMARSAT-C Safety Net AOR-W satellite. Fifty-two additional commands and organizations are

listed in the Ice Bulletin Address Indicator Group (AIG 8916).

The 1600Z and 1810Z Facsimile Chart depicting the Limits of All Known Ice is broadcast daily by U.S. Coast Guard Communications Station Boston NMF/NIK. It is also distributed to DMAHTCNAVWARN, NLMOC, and Naval Ice Center (NAVICECEN) for further dissemination.

IIP originates Safety Broadcasts of icebergs and stationary radar contacts reported outside the Limits of All Known Ice, if more than one hour before the next scheduled broadcast. These Safety Broadcast Notice to Mariners are broadcast by Communications Station Boston NMF/NIK, Radio Station St. John's/VON, DMAHTCNAVWARN Washington, and INMARSAT SAFETYNET. IIP also responds to routinely received requests for ice information. IIP also originates the NAVTEX broadcast message with the 0000Z and 1200Z Limits of All Known Ice for broadcast by Communications Station Boston NMK/NIK.

1.6 COSTS AND COST REIMBURSEMENT

The cost of operating the IIP in 1994 was approximately \$3.6 million, over 75% of which (\$2.7 million) covered the cost of surveillance. Regulation 6 of Chapter V of SOLAS 74 provides the opportunity for Contracting Governments to agree to pay a proportionate share of the cost of operating the IIP. Until 1991, 20 countries had agreed to support the cost of operating the IIP. At the end of the 1990 season, Liberia withdrew from the agreement following a series of severe internal political changes. Reimbursement is obtained through the Department of State. During the 1987-1991 period, average cost recovery was 69%. During that period, Liberia was one of the large non-payers. With Liberia's withdrawal, that proportionate share of the cost will be distributed to the other countries. The reimbursement is deposited in the General Treasury and is not credited against the Coast Guard's operating budget.

1.7 OTHER SERVICES

The IIP conducts significant scientific endeavors from time to time to support its operations. The results of those experiments along with complete descriptions of the conduct of the IIP are regularly published in an annual report in the CG-188-NR series. IIP also operates as a mini oceanographic unit providing limited marine science support to other missions such as: quality control of the FNMOC regional Gulf Stream current product that is entered into the Coast Guard Computer Assisted Search Planning (CASP) program and serving as a point of contact for Self Locating Data Marker Buoy (SLDMB) data in support of Coast Guard Search and Rescue. Three of the seven officer oceanographic billets in the Coast Guard are located at the IIP. Operationally, IIP serves as the communications center for the Coast Guard Research and Development Center and the Marine Safety Laboratory.

1.8 SUMMARY

Over its history, the IIP has been very effective in accomplishing its primary mission. While there has been occasional damage to vessels due to collisions between vessels and icebergs/growlers within the published Limits of All Known Ice, there are no reported collisions outside of those limits in the North Atlantic shipping lanes. There have been occasional sightings of icebergs outside of the Limits of All Known Ice which obviously are a cause for concern and deserve investigation. Part of this analysis addresses that issue. In the next section, the scope of the Cost and Operational Effectiveness (COEA) is addressed. In the following sections, COEA results are developed for the present system (termed the *Baseline*) and the COEA results are developed for the *selected* Alternatives.

2.0 OVERVIEW OF ALTERNATIVES BEING ANALYZED

This section provides an overview of the numerous alternatives that were generated and describes those alternatives that were selected by the Program Manager for a detailed Cost and Operational Effectiveness Analysis.

2.1 INTRODUCTION

The Cost and Operational Effectiveness Analysis study was designed with an objective to provide a fresh look at the structure and methods used to meet the International Ice Patrol mission. Phase I of the study involved first reviewing the present operations to ensure that the existing system was well understood. The interim report detailing this review (September, 1994) is included as Annex A. Concurrent with that review, various alternative methods for conducting the mission were identified. These included technological considerations as well as organizational/managerial considerations. The Statement of Work for the COEA directed that three alternatives be selected for a detailed COEA during Phase II of the study. An evaluation meeting was held with a panel convened by the Program Manager to select appropriate alternatives for detailed analysis. What evolved from that selection meeting was not three distinct alternatives, but rather a set of issues/alternatives covering managerial, technological, and operational elements that could be combined in various ways to represent a much larger set of alternatives. The development of the alternatives and the identification of the selected alternatives is included in a second interim report that is enclosed as Annex B to this report.

In addition to conducting a Cost and Operational Effectiveness Analysis (COEA) of the selected alternatives in Phase II, a COEA of the current operation (*Baseline*) was conducted. This latter analysis will likely yield additional alternatives representing incremental changes to the present system that will be available for the Program Manager's consideration.

2.2 MANAGEMENT ALTERNATIVES

Management alternatives represent options that will provide for the overall conduct of the IIP mission and meet existing performance requirements. Several alternatives are discussed in detail below. Two of the alternatives (Canadian management and National Ice Center management) were developed at the selection meeting when the CG control assumption was relaxed

2.2.1 Canadian Management

One new management alternative is to have the Canadian government assume the role of Managing Government under SOLAS 74. This option would necessarily require an amendment to the treaty. The existing infrastructure in the AES Ice Services Branch is fully capable of taking on the mission of the IIP. However, all Canadian governmental units are under strong pressures to reduce budgets. Absent any political motivation, it is unlikely that Canada would be willing to take on the full responsibility for the IIP without a strong guarantee of full reimbursement of the operating costs. A viable alternative involves Canada being assigned responsibility for day to day management of the entire IIP mission. An appropriate mechanism would be for the U.S. (perhaps through the Coast Guard) to subcontract with Canada to provide this service. The U.S. would remain as managing government and be responsible for collecting reimbursement.

2.2.2 National Ice Center Management

In the past, the National Ice Center has been interested in having the IIP responsibility shifted to its control. It is believed that the assumption was that the Coast Guard resources (e.g., personnel, aircraft support) would be included in such a shift. A change in responsibility to the NIC would require a change in the USC, but would not require an amendment to SOLAS because the U.S. would remain as the Managing Government. There is no apparent advantage to moving the responsibility to the NIC if the Coast Guard is still responsible for providing the resources and conducting the IIP mission. A potentially viable alternative is for the NIC to assume full responsibility for conducting the IIP including the funding of all operations.

2.2.3 Private Management under CG Direction

Another alternative is to have a private firm manage the IIP mission under Coast Guard direction/supervision. The intent is that the private firm would provide or contract for all services and functions required to meet performance specifications developed by the Coast Guard. With the

exception of some communications functions, no Coast Guard resources such as ships, aircraft, and personnel that have traditionally been used for IIP functions would be provided. Pursuing this alternative was considered as being beyond the scope of the present study.

2.2.4 Selected Management Alternatives

Two management alternatives were selected for the COEA in this analysis:

1. Canadian management. Because of the need to amend SOLAS to incorporate this alternative, it will be approached as U.S. management (Coast Guard) with all work contracted to Canada.

2. U.S. management with National Ice Center assigned responsibility. This alternative assumes that NIC will assume all IIP functions.

2.2.5 Miscellaneous Management Issues

Measuring the effectiveness of the IIP program is an ongoing concern. In 1993, a user survey was distributed. Limited response indicated a high level of satisfaction with IIP performance. It would be beneficial to obtain a larger response. It was agreed that Phase II should include a minor effort to conduct a user satisfaction survey. Several alternative mechanisms were explored to determine a cost-effective way of conducting the survey. Survey items were developed in conjunction with the Program Manager and CIIP.

2.3 TECHNOLOGY ALTERNATIVES

Technology alternatives include the several models used in the Data Management and Prediction System (DMPS) to estimate the positions of the icebergs and the processes and equipment that are use to transform sighting and environmental data into meaningful information. A number of alternatives were considered as described below. The alternatives are grouped as modeling alternatives, data acquisition alternatives, and data processing alternatives.

2.3.1 Modeling Alternatives

2.3.1.1 Major Revision to Existing Models

A clear alternative is to establish a major research effort to develop new drift and deterioration models. At this point, alternative models that are implementable with reasonably available input data do not appear to exist. This alternative fails the "proven technology" criterion used for the selection process. Moreover, the various studies discussed in Annexes A and B do support the reasonableness of the iceberg drift and deterioration models as approximating actual iceberg behavior.

2.3.1.2 Improve Model Input Data

All of the model evaluations suggest the need for better input data. However, there have been a number of modifications to the generation of the input data since those evaluations. In particular, FNMOC improved the wind, SST, sea height, and sea period inputs in 1988. In 1989-90, IIP modified the geostrophic current data base using observed data from drift buoys. This resulted in a significant reduction in current velocity estimates in a number of critical areas. To date, it is unknown how well these adjustments have caused the system data to more accurately reflect actual data. Further improvement in current estimates may be possible by the use of *objective analysis modeling* being developed by Applied Mathematics, Inc. through the CG R&DC for the SAR program. Objective analysis modeling involve using limited, sparse, or non-uniformly distributed oceanic data sets of either scalar or vector quantities, and providing a best estimate of how these may fit into a more uniform, gridded data field. The analysis also provides an estimate of the error of the fit.

Input data could be improved by using new means of collecting the critical data and using it directly in the model. Increased use of drift buoys and other devices for providing real time SST, local wind, and wave height/period data could be developed and deployed. However, there is no basis for concluding that such efforts would improve the forecasting without a better understanding of the entire system.

2.3.1.3 Probabilistic Model

The existing models depend on having estimated positions of the icebergs and then drift/deteriorate them over time so that some become the "extreme" icebergs and define the LAKI. Dr. Alan Washburn at the Naval Postgraduate School is currently engaged in a project to develop probability distributions that would characterize iceberg densities over the area normally enclosed by the LAKI. Such a model could be used to generate icebergs on a probabilistic basis that would then be drifted and ultimately determine the LAKI with some stated probability.

2.3.1.4 Integrated Risk Analysis

A final modeling alternative is to conduct a comprehensive sensitivity analysis of the system of models that is used to generate the LAKI. Such an approach requires a clear identification of the various data inputs as well as policies and assumptions, and the way that each influences other elements of the system. This analysis would evaluate the error propagation throughout the system and ultimately lead to the ability to characterize the risk associated with the model. This analysis should lead to identifying areas of potential refinement or improvement of the existing models, and should identify the need for areas of validation of these models.

2.3.2 Data Acquisition Alternatives

2.3.2.1 Digital Based Manual Data Collection and Transmission

The first data acquisition alternative essentially continues the existing system. It may be modified for ICERECDET sighting information as the existing AN/APS-135 SLAR is upgraded.

2.3.2.2 Digital Acquisition of Surveillance Data

Atlantic Airways Limited has developed the Airborne Data Acquisition & Management System (ADAM) which automates the tasks associated with airborne data collection. It is a real time data acquisition and management system that integrates aircraft position information and object position information obtained by digitally processing radar displays and graphically displays spatially distributed objects on a Mercator projection The ADAM system provides iceberg charts and prepares digital files in MANICE format. Commandant (G-EAE) has developed a similar system for Marine Environmental Protection activities and has a prototype system operating on a 486 portable computer. The prototype accepts navigational input, including GPS data, and object data entered by the operator.

2.3.2.3 Remotely Sensed Image Acquisition

If it is determined that some remotely sensed images are to be used in the analysis, it will be necessary to develop a capability to acquire such images. Such images could range from satellite images (e.g., NOAA, ERS-1, RADARSAT) to radar images. Under the alternatives presented above, information is extracted from the display and recorded digitally. The image is lost to further analysis.

2.3.2.4 Real Time Data Acquisition/Transmission

Real time data acquisition and transmission requires the availability of accessible communications links. This alternative applies to ICERECDET data. Iceberg sightings outside of the LAKI are reported immediately to IIP by message. The present system provides all of the flight data immediately following the aircraft return. This procedure is timely and there does not appear to be any significant advantage to providing real time data.

2.3.2.5 Automated Flight Path Planning

This alternative assumes that digital acquisition of surveillance data is incorporated along with the use of GPS for navigation. The alternative involves developing an algorithm to optimize the probability of detection of icebergs by setting the flight path relative to the surface wind.

2.3.3 Data Processing Alternatives

2.3.3.1 INTERGRAPH System With DMPS

Data processing alternatives will be compared with the existing system with the majority of the

system development being accomplished by ICEC. Although the existing INTERGRAPH system functions well, it is slow for large files and is experiencing some equipment failures. INTERGRAPH is prepared to upgrade the existing system. A major advantage of the existing system is the parallel operation with ICEC, but ICEC will be abandoning this system in 1996. Most of the enhancements to the existing system have been developed and funded by ICEC at no cost to IIP. Continued use of the INTERGRAPH system will preclude the use of remotely sensed images for direct analysis. This alternative to maintain the use of the INTERGRAPH system for DMPS will require the IIP to take primary responsibility for maintaining the system which will be very costly.

2.3.3.2 ISIS System

The ICEC has an ongoing project to develop an Ice Services Integrated System (ISIS) which will facilitate processing of multiple images and will fully integrate the satellite image processing, SAR/SLAR aircraft imagery, and all environmental data on a geocoded/georeferenced basis. ICEC will standardize on HP 9000 workstations for this system. Under the ICEC development plan, BAPS (DMPS) will be integrated into the system by the end of 1996. Implementation of such a system at IIP would provide a capability for using remotely sensed images. If images from RADARSAT would be effective in identifying icebergs, such a capability would be required. Actual use of such images would affect the personnel qualifications and training requirements and create a new analysis infrastructure.

2.3.3.3 Contracted Data Processing

Another data processing alternative is to contract with a third party (e.g., commercial firm, ICEC) to process data. Unfortunately, data processing within DMPS is an interactive process, requiring decisions at various points in the analysis. A major source of input judgment occurs in the resight and deletion analysis. Contracted data processing would be difficult to oversee by the Coast Guard.

2.3.3.4 DMPS on a New Operating System

A final alternative is to install DMPS on another graphics based operating system. This would require extensive development.

2.3.4 Selected Modeling Alternatives

Phase II should focus on conducting a detailed sensitivity analysis of the system and develop an approach to characterize the risk posture for the IIP (section 2.3.1.4). If this analysis identifies particular problems with specific data inputs, alternative methods of acquiring more reliable data should be evaluated.

2.3.5 Selected Data Acquisition Alternatives

The availability of ADAM or a system with similar capability makes this alternative one that should be considered in Phase II (section 2.3.2.2). It was concluded that real time data transmission is not required and need not be examined further. Similarly, there is no present need for acquisition of remotely sensed images. Although automated flight path planning may be valuable, it is not of high enough priority to be included in the Phase II COEA.

2.3.6 Selected Data Processing Alternatives

The selected alternatives are to examine the upgrade of the INTERGRAPH system and the switch to the ISIS system when its development is completed (section 2.3.3.2). The examination of these alternatives is intended to be a general comparison, not a detailed system design.

2.4 OPERATIONS ALTERNATIVES

Operations alternatives refer to different systems and approaches for iceberg detection, identification, and classification. These include satellite approaches, ground-based technology approaches, unmanned airborne approaches, and manned airborne approaches.

2.4.1 Satellite Systems

Satellite alternatives focused on those alternatives which satisfied the proven technology criterion and were accessible. There is no indication that

restricted access satellite systems exist that would provide the all weather resolution necessary to detect icebergs.

2.4.1.1 RADARSAT

RADARSAT, now scheduled for launch in mid-late 1995, will be operated by the Canadian Space Agency. RADARSAT will provide all weather coverage of the Canadian ice covered waters to facilitate ice forecasting for shipping. It has eight imaging modes. ICEC intends to primarily use the ScanSAR(Wide) mode with a swath width of 500 km and resolution of 100m. The finest resolution of 12x9 m is provided by the Fine Res mode with a 45 km swath width. The ICEC has concluded that the ScanSAR(W) mode will not be able to detect icebergs on a regular basis. However, it is possible that RADARSAT may provide early imaging of large icebergs upstream. To date, no one has explored the possibility of using a finer resolution mode. It is not known whether sufficient access could be provided on a regular basis to provide coverage of the IIP area of interest.

2.4.1.2 Other Satellite Systems

ICEC currently uses ERS-1 and NOAA AVHRR images in its sea ice program. The AVHRR images are infrared and hence dependent on visibility. The AVHRR swath width is 2700 KM with a resolution of 1.1 x 1.1 km. Clearly, even without clouds, AVHRR would not provide a reliable means of detecting icebergs. The ERS-1 C-band (VV polarization) SAR resolution is much better, approximately 30 m, but it has a smaller swath width of 80 km. It is unlikely that either system will contribute to iceberg detection.

2.4.2 Ground Based Systems

2.4.2.1 Ground Wave Radar

Northern Radar Systems Limited has built a prototype High Frequency Ground Wave Radar system at Cape Race, Newfoundland. Northern Radar claims nominal detection range of 125 nm for large icebergs. They have planned a major upgrade to provide 150 nm detection of small icebergs and 250 nm detection of large icebergs. The system is also supposed to provide for measurement of surface currents, waves and sea state, and surface wind. ICEC evaluated the GWR performance comparing their reports with the results of IIP flights in the same area on May 30 - June 1, 1992 and concluded that there was little correlation between the Cape Race GWR reports and the IIP observations. It should be noted that "Iceberg Alley" is 200 nm from Cape Race.

2.4.2.2 SOSUS

A second ground based alternative is the use of the installed SOSUS system. The mechanisms by which icebergs make sounds and any characterization of a frequency spectrum for icebergs are unknown. It appears that the sensor locations and the inability to accurately identify icebergs make this alternative unlikely to be able to accomplish the mission objectives.

2.4.3 Unmanned Aerial Systems

2.4.3.1 U.S. Army UAV

The U.S. Army is developing an Unmanned Aerial Vehicle (UAV) with the following specifications: 24 hours continuous coverage at 500 nm range; altitude range from 3,000 to 25,000 ft; and a payload capacity of 450 pounds. An extended range capability is being developed as is a deicing capability. The UAV is operated with a ground control station and datalink. The estimated system cost is $10 million. A detailed description of the UAV operation is included in Annex M.

2.4.3.2 AMERIND "Predator"

AMERIND is currently developing a UAV as a technology demonstration project for the Undersecretary of Defense. The drone, termed the "Predator," will cover 500 nm at an altitude up to 25,000 ft. and will loiter up to 60 hours in an area. The drone carries a Westinghouse SAR. A ground control station must be located at the airport where the vehicle takes off and lands. The GCS must be operated by a licensed pilot. The drone currently has no deicing capability. It is the size of a large Cessna. System cost is approximately $13 million for four vehicles and a GCS. The vehicle flies on a satellite which requires purchasing channels and time for communications links.

2.4.4 Manned Airborne Surveillance

2.4.4.1 Improved USCG Surveillance

This alternative continues the present operation, but explores alternative ways of improving the effectiveness of that operation. The installation of GPS and the digital processing upgrade to the AN/APS-135 SLAR should present opportunities for improved performance. The recent experience in the joint use of the AN/APS-137 FLAR with the installed SLAR suggests better performance (Ezman, Murphy, Fogt, and Reed, 1993). It has not been determined how that better performance may impact issues such as selection of the search area. Additionally, new FLAR enhancements for periscope mode imaging may provide additional identification capability. Finally, the cost and effectiveness of available SAR systems such as the STAR-2 would be investigated.

2.4.4.2 Canadian Surveillance

One of the selected management alternatives for Phase II is Canadian Management of the IIP. One element of that alternative would be for Canada to provide the surveillance necessary to generate the ice information. A separate alternative would involve continued U.S. management of IIP (presumably the Coast Guard) with surveillance contracted to Canada. The ICEC Dash-7 will have excess capacity with the arrival of RADARSAT. Given the permanent location in Gander, ICEC suggests that they may be able to perform the surveillance mission at a lower cost than deploying a HC-130 to St. John's. In addition, they would have more flexibility in choosing when to fly to take advantage of visibility and thereby improve the identification/classification problem. ICEC would be willing to modify the sensor suite to meet the mission requirements.

2.4.4.3 Commercial Contracted Surveillance

As another alternative, contracting surveillance to commercial firms is technically feasible. Both Intera Technologies Limited and Atlantic Airways Limited provide ice surveillance to ICEC. Atlantic Airways is the single largest contributor to IIP sightings. Intera Technologies completes its contract with ICEC in March, 1995.

2.4.4.4 DOD Surveillance

A final source of surveillance is the Department of Defense. Historically, DOD assets have been available on special occasions. It is unlikely that they could be committed on a regular basis to conduct iceberg surveillance flights.

2.4.4.5 Selected Operations Alternatives

The satellite systems offer little promise in the near future for assisting in the detection of icebergs in the IIP area of responsibility. Certain aspects of RADARSAT may be useful for supplemental information and should be examined further.

The ground based systems appear to be very marginal. The upgrade to the Cape Race GWR should be examined in more detail and appropriate costs identified. It may have a role as a supplemental source of information.

Neither of the UAV systems are sufficiently well developed. The initial costs are significant and the operating costs (pilots, maintenance, etc.) are not known. Further analysis at this time is not appropriate.

DOD airborne surveillance is not feasible on a regular and cost-competitive basis. Certain radar decisions (e.g., digital upgrade of the AN/APS-135 SLAR on HC-130H aircraft) have been made for CG surveillance based on cost and standardization concerns. Nonetheless, the effectiveness of the resulting system has to be evaluated and opportunities for operational savings identified. Finally, the possibility of contracting surveillance is a viable alternative.

The following operations alternatives were selected for detailed analysis in Phase II:

1. Brief examination of RADARSAT and Ground Wave Radar systems.
2. USCG HC-130 surveillance using SLAR/FLAR combinations and possibility of SAR installation.

3. Surveillance contracted to Canada (ICEC/ISB).

4. Surveillance contracted to commercial firms (Atlantic Air, Intera Technologies).

3.0 CURRENT IIP OPERATIONS BASELINE

The three categories of alternatives require a baseline against which specific alternatives can be measured. The overview of the IIP provided a basic structure for understanding the potential alternatives. This section provides significant detail on current operations and forms a basis for evaluation of the alternatives.

3.1 MANAGEMENT

3.1.1 Organizational Foundation

3.1.1.1 Authority and Structure

The basic authority for conducting the IIP is provided by SOLAS 74, Chapter V, Regulations 5-8 and 46 USC 738, 783(a)-(d). Under provisions of the SOLAS treaty, the United States is the Managing Government for the IIP. Day to day management responsibility is assigned to the U.S. Coast Guard. Commander, International Ice Patrol, located at Groton, CT operates under the operational control of Commander, Atlantic Area.

Responsibility for provision of ice patrol and related services falls under the Ice Operations Program under the Marine Science section. The function which provides the actual ice patrol services and related functions is termed the International Ice Patrol. The specific responsibilities for the International Ice Patrol are identified in Objective #3 of the Ice Operations Program:

> Provide mariners in the Northwest Atlantic Ocean with information on the limits of known icebergs to facilitate safe navigation.

In order to support this objective, the International Ice Patrol performs/coordinates the following:

- Conduct reconnaissance flights to locate and track icebergs that may become a hazard to navigation and to identify the limits of known icebergs.
- Obtain environmental data on iceberg drift and deterioration to predict future iceberg positions.
- Disseminate information on the location and drift of icebergs to mariners crossing the Northwest Atlantic.

The present Program Standard is "to ensure that vessels transiting the Northwest Atlantic Ocean have the most current and accurate information available on icebergs."

The present measure of effectiveness for the IIP is the casualty rate (actually computed as a *safety* rate) and defined as follows:

$$\text{Casualty Rate} = 100\% - \frac{\#\text{ vessels damaged}}{\#\text{ vessel transits}} * 100$$

The Chief, Office of Navigation Safety and Waterway Services (G-N) is the Program Director for IIP. Management responsibility has been assigned to Chief, Ice Operations Division (G-NIO) as the Program Manager and further assigned to Chief, Science Branch (G-NIO-3) for managing the IIP. The Program Manager is responsible for the overall conduct of the IIP and is the key liaison with the Department of State and other agencies/governments with regard to ice patrol policy.

The Commandant has assigned responsibility for the conduct of the International Ice Patrol to Commander, Atlantic Area. The direction is provided in Commandant (G-NIO) letter serial 3145 dated October 11, 1988 which specifies that Commander, Atlantic Area use ships, aircraft, and command and control facilities to meet the requirements of ice patrol service as specified in 46 USC 738, 738a through 738d and SOLAS (1974). This letter authorizes direct liaison between IIP and other Coast Guard commands, between IIP and various U.S. government and military agencies, and between the IIP and various Canadian agencies for conducting the ice patrol service.

The mission objectives of the IIP as presented in the *Standing Orders for IIP Operations Center*

Duty Personnel (CIIPINST M3120B dated 18 December 1992 [CH-2]) are:

a. To observe icebergs in the northwestern Atlantic Ocean in the vicinity of the Grand Banks of Newfoundland.

b. To identify the southeastern, southern, and southwestern limits of the iceberg region.

c. To inform mariners of the extent of the danger area based on all known iceberg and sea ice information.

The recent Measures of Effectiveness workshop conducted on March 14-15, 1994 stated the mission of the IIP as follows:

1. Provide International Ice Patrol service to the mariner.
2. Provide marine science activity support to other Coast Guard programs.

This workshop identified three Goals that support this mission:

1. Warn mariners of the limits of iceberg danger in the vicinity of the Grand Banks.
2. Determine the limits of the iceberg danger throughout the ice season.
3. Provide value added marine science activity support to operational commanders.

An effective operational definition of the IIP mission is to **determine the Limits of All Known Ice along the southeastern, southern, and southwestern edge of the ice region in the vicinity at the Grand Banhs of Newwfoundland and publish that information to mariners in a timely fashion.**

This mission involves data and information acquisition, processing, and distribution--finding out where the ice danger is for trans-Atlantic shipping and telling the mariner so as to prevent ship-iceberg collisions. The primary products of the IIP are the 0000Z and 1200Z Ice Bulletins and the 1200Z Facsimile Ice Chart that depict the Limits of All Known Ice (LAKI) with positional information on selected icebergs and radar targets and safety broadcasts as required. Knowledge of icebergs in the interior of that region is an objective only to the extent that it provides information for determining the Limits of All Known Ice. This mission statement is considered to be controlling for purposes of the present analysis.

3.1.1.2 Organization and Operations

The personnel allowance and functional assignments for the IIP are indicated in Table 1. The total allowance is 16 officer, enlisted and civilian personnel. The officers assigned to the IIP typically have advanced degrees in oceanography. Senior officers generally have had a previous assignment at the IIP or have had an otherwise close working relationship with the IIP. The average officer and enlisted tour is three years.

The IIP maintains a continuous Duty Watch Officer (DWO) and Watchstander (WS) in the IIP Operations Center during the day and on call at night throughout the year. During the ice season, the IIP DWO is responsible for executing the mission of the IIP by receiving iceberg and radar tar-

Table 1: IIP Personnel Allowance and Functions.

Billet	Responsibility	Allowance
CDR (0-5)	Ice Patrol Commander	1
LCDR (0-4)	Deputy Commander Senior Watch Officer Senior Ice Observer	1
LT (0-3)	Ice Patrol Officer Duty Watch Officer Senior Ice Observer	1
LT (0-3)	Science Officer Duty Watch Officer Senior Ice Observer	1
MSTCS (E-8)	Duty Watch Officer Senior Ice Observer	1
MST1 (E-6)	Duty Watch Officer Senior Ice Observer	2
YN1 (E-6)	Administration	1
MST2 (E-5)	Watchstander, Ice Observer	3
MST3 (E-4)	Watchstander, Ice Observer	3
Civilian (GS-14)	Chief Scientist	1
Civilian (GS-11)	Computer Specialist Computer Systems Manager	1

get reports; analyzing this information; receiving environmental information; running the computer drift and deterioration prediction models; and producing the IIP products to serve the mariner. The DWO and WS follow the instructions in the *CIIP Standing Orders for IIP Operations Center Duty Personnel* and the *CIIP Computer Documentation Manual*.

Staffing the ICERECDET is another major function of the IIP during the ice season. ICERECDETs are normally deployed for a period of nine days (two days enroute, five days of patrols, one day air crew rest, and one day aircraft maintenance). IIP staffing includes one Senior Ice Observer and three or four Ice Observers. Eleven or twelve air crew members complete the ICERECDET.

The knowledge requirements for the IIP are unique among Coast Guard commands. Assignment and rotation of duty watch officers/senior ice observers to the IIP by Commandant requires careful attention because of the training and qualification process. During the ice season, when an ICERECDET is deployed, three watchstanders and four Duty Watch Officers (not including the Deputy Commander) are available for watches. This leads to a one in four rotation for DWOs and an one in three rotation for watchstanders. During the ice season, the opportunity to take leave is severely restricted, both as to the number of personnel on leave simultaneously and to the amount of leave taken (maximum of one week). Duty personnel will typically spend about 10-12 hours in the IIP Operations Center and be available by telephone or beeper during the remainder of their 24 hour watch. Watchstanding requirements are relaxed during the off-season, but leave and training absences continue to restrict the ability to reach a one in six watch rotation. One SIO and two or three ice observers constitute the IIP staff component of the ICERECDET. Under good weather conditions, five patrols will be conducted during the deployment. The duration of a typical patrol is 8-10 hours. The ICERECDET personnel rotate among the SLAR, FLAR, and visual observer functions. The SIO oversees the operation and makes the determinations as to the identification/classification of radar targets. Present policy allows one day of compensatory time following the return from an ICERECDET deployment.

3.1.1.3 Relationships With Other Agencies

The acquisition and distribution of ice information requires that IIP establish and maintain close working relationships with a number of organizations and agencies. A key liaison is with the Atmospheric Environment Service of Canada which operates ICEC. The existing computer system at IIP was initially designed for their use and the DMPS is an adaptation of the BAPS program. This close coordination has substantially reduced the development costs for IIP equipment and software. In addition, AES provides important iceberg sighting information to the IIP. Similarly, the Canadian Department of Fisheries and Oceans, through its contracted service with Atlantic Airways, provides substantial sighting data to IIP. Other major external relationships include the National Ice Center, FNMOC, and NLMOC. The primary nature of these relationships involves the acquisition of environmental data used in the drift and deterioration models. The nature of each specific relationship is dictated by the purpose of the activity. In some cases, there will be frequent contact and facility visits.

The IIP maintains significant liaison with numerous communications facilities. The most important relationship is with Coast Guard Communications Station Boston NMF/NIK which broadcasts both the facsimile chart and the ice bulletins.

Key internal (Coast Guard) relationships include the First Coast Guard District, the Atlantic Area Operations Staff, the Program Manager, and Coast Guard Air Station Elizabeth City. A very important internal relationship is with the Coast Guard Research and Development Center. The IIP relies on the R&DC for a significant amount of personnel and administrative support, including procurement activities. The IIP is a tenant in the R&DC facility with housekeeping responsibilities only in the designated office spaces. Beyond this physical support, the R&DC has developed a significant expertise in areas relevant for the IIP through its close working relationship over the years. Main-

taining this liaison with the R&DC and its key personnel contributes to the effectiveness of the IIP operation.

3.1.2 Costs and Operations

3.1.2.1 Cost Drivers

Coast Guard cost development/allocation is usually based on direct costs incurred by an operational unit, personnel costs attributable to that unit, and the cost of services provided to that unit by other operational, operational support, and administrative units. Cost allocation is similar to an activity based costing approach to permit more effective resource management. Such an approach requires clear identification of cost drivers. Figure 4 illustrates the relationships among the various cost drivers for the International Ice Patrol. A detailed treatment of cost development for the IIP is included in Annex E.

The cost of the operation of Commander, International Ice Patrol (CIIP) includes personnel costs, facility maintenance costs, travel costs associated primarily with the deployment of the ICERECDET, operational support costs, administrative support costs, and services such as data collection for WOCE buoys. In the short term, of these costs, only the ICERECDET travel is volume-dependent (based on the number of deployments). The cost is slightly affected by decisions regarding the number of personnel to deploy.

Specific ICERECDET costs include certain facility costs as well as the costs associated with the deployment and operation of the CG surveillance aircraft. These costs are volume-dependent, both on the number of deployments and the number of flight hours required. The air station related costs are volume-dependent based on the number of flight hours deployed and the actual fuel costs incurred. The annual aircraft personnel, maintenance, operational support, and depreciation costs

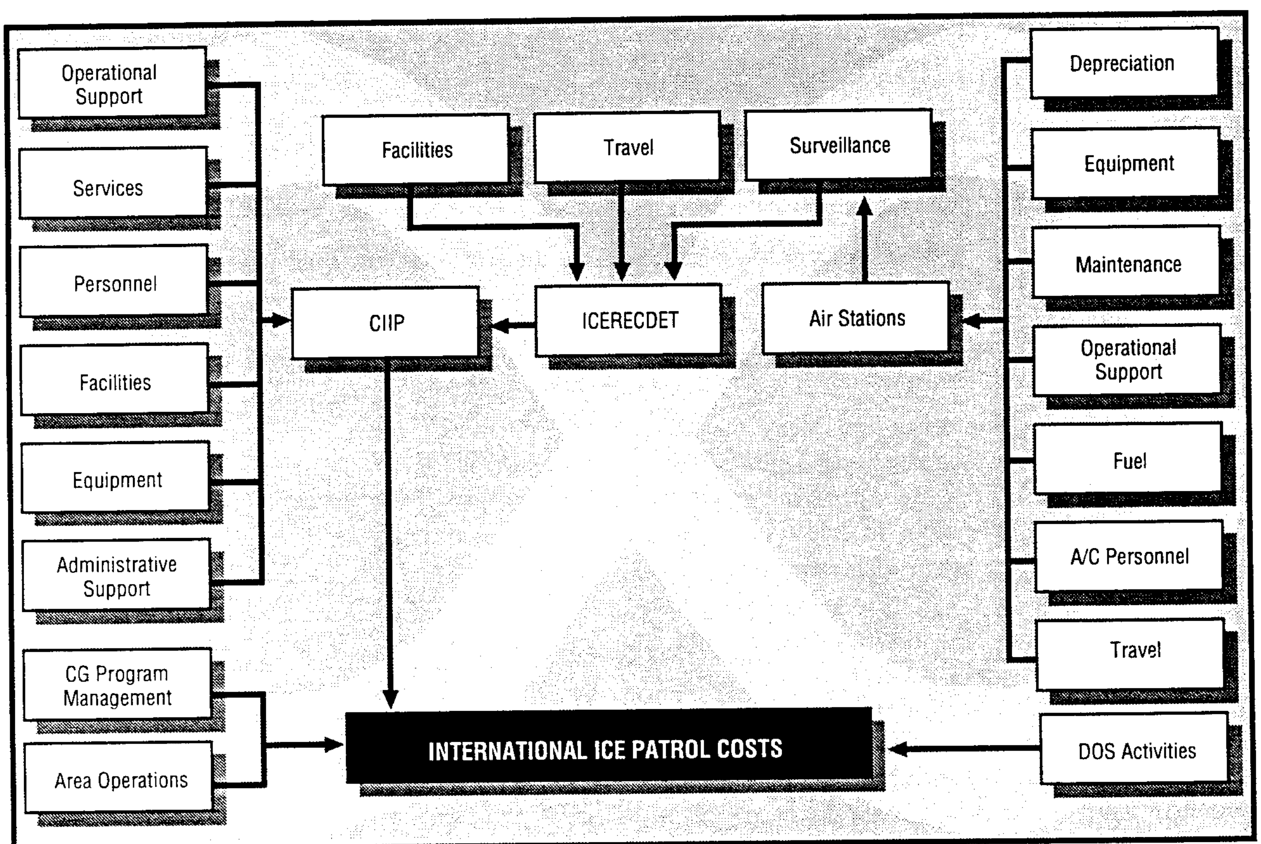

Figure 4. International Ice Patrol Cost Drivers.

are allocated in proportion to the number of flight hours as compared with the programmed standard flight hours for the aircraft type. Actual travel and equipment costs are identified separately.

Other program costs include the expenses associated with program management, area operations costs, and activities conducted by the Department of State with respect to cost reimbursement and other treaty issues. The program management costs necessarily include the office of the Program Manager (G-NIO) and the Program Director, as well as other supporting units in Coast Guard Headquarters. In addition, there are some costs incurred by Commander, Atlantic Area staff (Aoa). Finally, the costs of the Department of State as related to IIP should be included.

3.1.2.2 Cost Development

At the end of each ice season, Commander, International Ice Patrol prepares an annual report that identifies various costs associated with the operation of the IIP. The report is submitted to Commandant (G-CFM) where it is forwarded to CG FINCEN for further analysis. The direct costs reported by CIIP are related to the cost drivers in Table 2 for the 1994 ice season to illustrate the causal aspects of the costs. The data are also displayed in Figure 5.

The CG Finance Center uses the CIIP reported costs and other information and then applies costs based on standard rates to compute a total cost for the operation of the IIP. It is this total cost that is forwarded to the Department of State for cost reimbursement from the contributing governments. A detailed breakdown of the CG FINCEN costs for 1992-1994 is included in Annex E (Appendix II). The CG FINCEN computed costs of IIP operations for 1990-1994 are compared in Table 3. Note that the CIIP reported costs in Table 2 only constitute a portion of the total cost in Table 3 for 1994. Personnel, maintenance, and support costs account for the difference.

To better understand the cost development, the results of the computation for 1994 are included in Table 4. The aircraft costs are computed using standard per hour personnel, maintenance and operational support costs as adjusted for inflation. The IIP personnel costs are computed using actual pay grades assigned for the months in which they were engaged in IIP activities. Prior to 1994, only the portion of the personnel costs corresponding to the duration of the "official" season was included, despite the fact that IIP personnel were generally engaged in IIP activities for the entire year. For 1994, it is assumed that the total annual personnel costs of CIIP are devoted to IIP activities unless otherwise stated. The administrative expense computed by the CG FINCEN is 30% of the aircraft operational costs.

Note that the Office of CIIP costs increased significantly in 1994. This reflects the change in policy

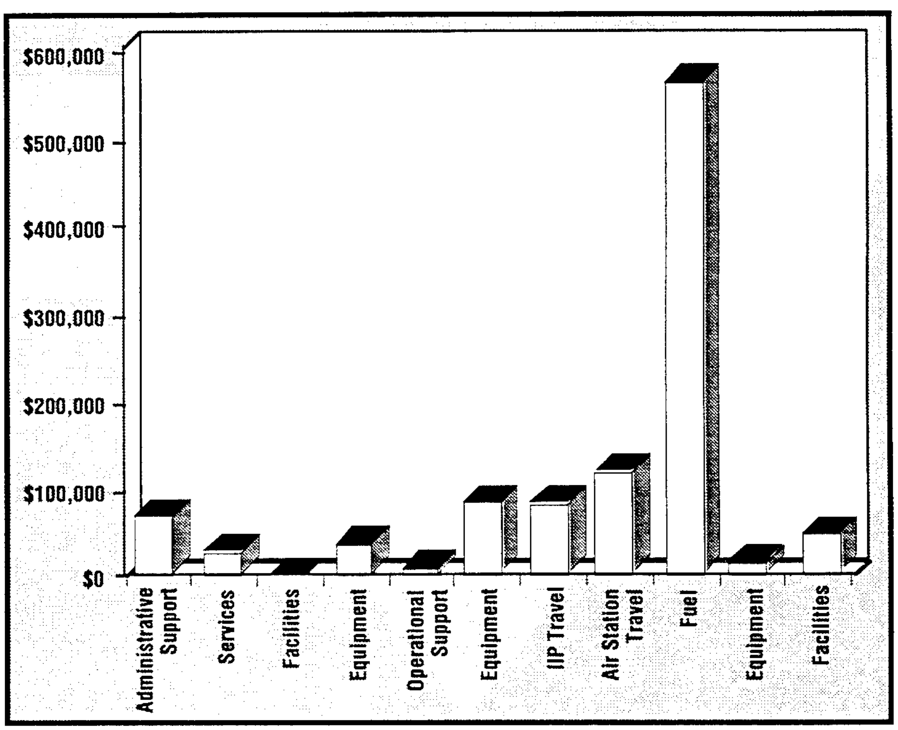

Figure 5. IIP Costs by Cost Drivers, 1994.

Table 2: CIIP Costs by Cost Drivers, 1994.

1994 IIP SEASON COSTS	COMMANDER, INTERNATIONAL ICE PATROL					ICERECDET		AIR STATION			
	ADMINISTRATIVE SUPPORT	SERVICES	FACILITIES	EQUIPMENT	OPERATIONAL SUPPORT	EQUIPMENT	IIP TRAVEL	AIR STATION TRAVEL	FUEL	EQUIPMENT	FACILITIES
HC-130 Fuel									$557,200		
HU-25 Fuel									$5,841		
Contract Lodging							$37,985				
IIP Travel							$42,863				
CGAS E City Travel								$115,000			
CGAS Cape Code Travel								$2,200			
Leased Flight Services (E City)											$46,755
Leased Flight Services (Cape Code)											$245
Drifting Buoys						$67,345					
Air Drop Packages for Drift Buoys						$13,075					
Buoy Data Processing		$27,555									
IIP Operations	$64,886										
IIP Bulletins/Public Affairs	$3,435										
Maintenance Services				$34,508							
Telex Charges (CGDONE COMCEN)					$9,000						
SLAR Film (E City)										$13,000	
SLAR Film (Cape Code)										$700	
Cost Driver Totals	$68,321	$27,555	$0	$34,508	$9,000	$80,420	$80,848	$117,200	$563,041	$13,700	$47,000
CIIP Totals	$139,384										
ICERECDET Totals						$161,268					
Air Station/Surveillance Totals								$740,941			
Total Season Cost	$1,041,593										

Table 3: CG FINCEN Cost Comparisons, 1990-1994.

TOTAL IIP COSTS	1994	1993	1992	1991	1990
Aircraft Hours	***576.7***	***650.2***	***612.5***	***601.5***	***352.5***
Aircraft Costs	$1,989,100	$2,008,500	$2,026,000	$1,839,800	$951,100
Office of CIIP	$864,200	$516,600	$545,900	$518,700	$359,000
IIP Computer Acquisition	$0	$0	$30,400	$314,300	$0
Other Costs	$168,600	$117,600	$108,700	$95,900	$96,200
Administrative Expense	$596,700	$602,600	$607,800	$533,500	$275,800
TOTAL COSTS	$3,618,600	$3,245,300	$3,318,800	$3,302,200	$1,682,100

Table 4: Total IIP Cost Development, 1994.

1994 IIP COSTS	CG FINCEN	CIIP GENERATED
OFFICE OF CIIP		
Personnel	$736,400	☆
Travel and Lodging	$80,800	$80,848
Leased Property	$47,000	$47,000
Total Office Costs	$864,200	$127,848
AIRCRAFT COSTS		
Personnel	$502,000	☆☆
Fuel	$563,000	$563,041
Maintenance	$492,500	☆☆
Operational Support	$431,600	☆☆
Air Station Travel	☆☆☆	$117,200
Total Aircraft Costs	$1,989,100	$680,241
IIP COMPUTER ACQUISITION		
Hardware	$0	$0
Total IIP Acquisition Costs	$0	$0
OTHER COSTS		
Buoys	$80,400	$80,420
Radar Film	$13,700	$13,700
Miscellaneous	$74,500	$139,384
Total Other Costs	$168,600	$233,504
ADMINISTRATIVE EXPENSE		
30% of Total Aircraft Costs	$596,700	$0
TOTAL COSTS	$3,618,600	$1,041,593

NOTES:

☆ CIIP Personnel Costs Computed Using Standard Rates

☆☆ Personnel, Maintenance and Operational Support Costs Computed Using Standard Rates for Flight Hours

☆☆☆ Air Station Travel is Not Explicitly Included
CG FINCEN Miscellaneous Cost Did Not Include $64,886 IIP Operations Expense

to charge personnel costs for the entire year and not just the portion of the year during which the IIP was officially in operation. It is suspected that the prior costing policy was established when CIIP was formed from the Commander, Atlantic Area staff for a fraction of the year. The other variation in cost over the years is due to the length of the season and the number of flight hours flown. The aircraft costs and the associated administrative expense are clearly volume-dependent costs.

Certain costs may be misleading on an annual basis. For example, the 1994 buoy costs were high due to the cost submission timetable. During FY93, but after the 1993 ice season closure, IIP placed a $23,000 order which was included in the 1994 costs as it was a buy-ahead for the 1994 season. Annual buoy orders are approximately $45,000. Other buy-aheads were included in the "IIP Operations" line for the 1994 season, thereby increasing that total.

In practice, some costs are treated as annual and others are treated based on the ice season. Consistency would follow if IIP cost submissions were made 30 days after the end of the fiscal year rather than 30 days after the ice season.

3.1.2.3 Cost Analysis and Review

Table 4 provides some significant information regarding the current costing procedures. One inconsistency is the failure of CG FINCEN to use the Air Station travel costs ($117,200) as directed in COMDTINST 7310.1E. Another concern is the failure to include $64,886 for IIP Operations. Additionally, no charge is made for depreciation for the aircraft ($210 per hour for HC-130 and $410 per hour for HU-25–1991 dollars). This total charge is $145,637 using a 5% inflation factor to adjust to 1994 dollars. Finally, it appears that an administrative expense should be computed on the operational costs exclusive of aircraft costs. This amounts to 30% of ($864,200 + $233,504) = $329,311. After making these adjustments, the actual cost of the 1994 IIP season should be $3,618,600 + $117,200 + $64,886 + $145,637 + $329,311 = $4,275,634, approximately 18% higher than the previously computed cost.

The administrative expense is intended to cover the related costs associated with Headquarters, Area, MLC, and District Offices. Inclusion of this expense will cover the CG Program Management and Area Operations cost drivers in Figure 4. This also covers some of the Operational support and Administrative support activities. Not explicitly accounted for is the administrative support and facilities support that CIIP receives from the Coast Guard Research and Development Center and from the Coast Guard Academy. This support involves provision of operating facilities as well as financial management and procurement support. External management costs such as those associated with the Department of State are not included.

Based on this review, it appears that the Coast Guard is systematically underestimating the actual cost of conducting the IIP. For the 1994 ice season, it appears that the actual cost was $657,034 greater than that reported to the Department of State and billed to the contributing government.

3.1.2.4 Baseline Cost Development

This review of existing costing procedures provides a basis for estimating the baseline cost of operating the International Ice Patrol. Baseline costs depend on assumed activity levels and identification of transaction-dependent costs and volume-dependent costs. Transaction-dependent costs are those that are incurred when the operation is conducted or a particular transaction is executed (e.g., execution of a maintenance contract). Volume-dependent costs are those that depend on the level of activity (e.g., number of ICERECDET deployments, flight hours patrolled). Assuming the present IIP personnel allowance as the baseline (see Table 1), the baseline personnel costs can be computed using standard personnel costs for 1995 (Annex E, Table 3). The resulting personnel baseline costs are included in Table 5.

To compute the estimated IIP baseline costs, it is assumed that there will be approximately 15 ICERECDET deployments and that there will be approximately 600 flight hours required for HC-130 aircraft to support surveillance operations. Those levels are approximately the levels experienced over the past four years. It is also assumed that there will be a continuing effort to deploy and track drift buoys at approximately the same level as 1994. Most of the projected costs correspond to the 1994 cost levels. In addition, the baseline costs include aircraft depreciation and full administrative expenses based on operational costs at the present 30% rate. The detailed cost estimates are summarized in Table 6.

The flight hour cost used in Table 6 is approximately the cost observed in 1994. In comparison with the standard cost in COMDTINST 7310.1E (see Annex E, Table 1), the 1995 estimate follows using a 1.8% inflation rate. Note that the adjusted IIP cost for 1994 was $4,275,634 which is slightly less than the 1995 IIP Baseline cost of $4,569,222 computed in Table 6. The slight increase is due primarily to the increased personnel costs in Table 5 and the corresponding administrative expense. A small amount was provide for IIP science projects, although there are no provisions for significant IIP research (e.g., oceanographic cruises). There are no funds provided for computer equipment.

3.1.2.5 Allocated Costs vs. Real Costs—Potential Cost Reductions

Table 6 includes a column to indicate whether the individual cost elements are controllable. In this context, controllable determines whether cost reductions are possible, and generally corresponds to volume-dependent activities. It is also important to identify what costs would actually be reduced with a reduction in the level of program activity and would represent a cash savings to the Coast Guard if certain aspects of the program were changed. The results of this analysis are included in Table 7.

Table 7 indicates that if all IIP operations were terminated, the Coast Guard would realize immediate cost reductions

Table 5: IIP Personnel Baseline Costs, 1995.

		1995 STANDARD COSTS					
IIP ALLOWANCE	NO.	SALARY	PCS	O&M	TRAINING	MEDICAL	
CDR (0-5)	1	$77,352	$1,858	$3,257	$1,431	$2,917	$86,815
LCDR (0-4)	1	$65,346	$1,858	$3,257	$1,431	$2,917	$74,809
LT (0-3)	2	$59,031	$1,858	$3,257	$1,431	$2,917	$136,988
MSTCS (E-8)	1	$47,038	$1,416	$2,999	$672	$2,917	$55,042
MST1 (E-6)	2	$34,609	$1,416	$2,999	$672	$2,917	$85,226
YN1 (E-6)	1	$34,609	$1,416	$2,999	$672	$2,917	$42,613
MST2 (E-5)	3	$29,249	$1,416	$2,999	$672	$2,917	$111,759
MST3 (E-4)	3	$24,008	$1,416	$2,999	$672	$2,917	$96,036
GS-14	1	$86,300	$503	$2,506	$244		$89,553
GS-11	1	$54,500	$503	$2,506	$244		$57,753
TOTAL PERSONNEL COST							$836,594

Table 6: IIP Baseline Costs, 1995.

		TRANSACTION-DEPENDENT	VOLUME-DEPENDENT	CONTROLLABLE
CIIP				
Personnel		$836,594		No
Services				
Buoy Data Processing		$28,000		Yes
Equipment Maintnenace		$35,000		No
Telex		$9,000		No
Equipment				
Drifting Buoys		$67,000		Yes
Air Drop Pacages		$13,000		Yes
Computer Equipment				
Administrative Support				
IIP Operations		$65,000		No
IIP Bulletins/Public Affairs		$3,500		No
Science Operations		$15,000		Yes
Administrative Expense	30%	$321,628		
Total CIIP Costs		**$1,393,722**		
ICERECDET				
Assumed Deployments	15			
IIP Travel			$42,000	Yes
Contract Lodging			$38,000	Yes
Administrative Expense	30%		$24,000	
Total ICERECDET Costs			**$104,000**	
Surveillance/Air Station				
Assumed Flight Hours	600			
HC-130 Facility Cost Per Hour	$3,450			
HC-130 Depreciation Cost Per Hour	$255			
Personnel/Fuel/Maint/Ops Support HC-130 Facility Costs			$2,070,000	Yes
HC-130 Depreciation			$153,000	No
Air Crew Travel			$115,000	Yes
Facilities				
Leased Flight Services			$47,000	Yes
Equipment				
SLAR Film			$13,000	Yes
Administrative Expense	30%		$673,500	
Total Surveillance/Air Station Costs			**$3,071,500**	
BASELINE COST			***$4,569,222***	

and cash savings of $477,500. In addition, if the 16 CIIP personnel were separated, additional cash savings in the amount of $836,594 would be realized. If the personnel were simply transferred to other operating units, no savings would be realized, but presumably another program would absorb their cost. Finally, additional cash savings in the amount of $2,070,000 would be realized if the portion of the HC-130 that flies IIP missions was disestablished. The remaining $1,185,128 represents administrative expense (overhead at 30%) and aircraft depreciation costs, amounts that do not represent cash savings if the program was disestablished. Without the IIP, these costs would be shifted to other programs.

In summary, the real potential savings to the Coast Guard if the IIP was disestablished ranges from approximately $477,500 to $3,400,000 depending on whether personnel, aircraft, and direct aircraft operational support activities were eliminated.

3.1.3 Cost Reimbursement

3.1.3.1 Authority for Cost Reimbursement

A complete baseline analysis of cost reimbursement for IIP operations is included in Annex D to this report. SOLAS 74 provides for distributing the cost of operating the Ice Patrol among those signatory countries which benefit from the ice patrol service. Regulation 6 of Chapter V provides the authority for the United States to manage the ice patrol service and obtain reimbursement for operating costs. Specifically, "each Contracting Government specially interested undertakes to contribute annually to the expense of maintaining and operating these services a sum determined by the ratio which the total gross tonnage of that Contracting Government's vessels passing during the ice season through the regions of icebergs guarded by the Ice Patrol bears to the combined gross tonnage of the vessels of all contributing Governments

Table 7: Potential Cash Savings with Program Changes.

MODIFICATION	COST	CERTAIN SAVINGS	POTENTIAL SAVINGS	REQUIREMENT/STATUS
Eliminate St. John's Deployment				
Leased Flight Services	$47,000	$47,000		
Air Crew Travel	$115,000	$115,000		
SLAR Film	$13,000	$0		SLAR Film is in Inventory
IIP Travel	$42,000	$42,000		
Contract Lodging	$38,000	$38,00		
HC-130 Facility Costs	$2,070,000		$2,070,000	Requires Laying Up One HC-130
HC-130 Depreciation Costs	$153,000	$0	$0	
ICERECDET Admin Expense	$24,000	$0	$0	
Surveillance Admin Expense	$673,500	$0	$0	
Total Commander IIP Expenses	**$3,175,500**	**$242,000**	**$2,070,000**	
Eliminate Drift Buoy Program				
Buoy Data Processing	$28,000	$28,000		
Drifting Buoys	$67,000	$67,000		
Air Drop Packages	$13,000	$13,000		
Drift Buoy Admin. Expenses	$32,400	$0	$0	
Total Buoy Program Expenses	**$140,400**	**$108,000**	**$0**	
Eliminate CIIP				
Equipment Maintenance	$35,000	$35,000		
IIP Operations	$65,000	$65,000		
IIP Bulletins/Public Affairs	$3,500	$3,500		
Science Operations	$15,000	$15,000		
Telex Charges	$9,000	$9,000		
CIIP Admin Expense	$289,228	$0		
Personnel	$836,594		$836,594	Requires 16 People Be Dismissed
Total CIIP Expenses	**$1,253,322**	**$127,500**	**$836,594**	
TOTAL COST	***$4,569,222***	***$477,500***	***$2,906,594***	

Currently, 19 countries have agreed to support the IIP. Liberia withdrew from the agreement following the 1990 season.

The specific cost allocation regime from paragraph (a) of Regulation 5 above is also included in the multilateral Agreement regarding financial support of the ice patrol titled "Safety of Life at Sea: Financial Support of the North Atlantic Ice Patrol" which entered into force on July 5, 1956 (TIAS 3597). This Agreement identifies the routes passing through the regions of icebergs. This generally includes all routes to or from Atlantic and Gulf coast United States and Canadian ports passing through or north of the Straits of Gibraltar.

For purposes of calculating the tonnage in the cost allocation formula, the ice season is considered to be the period from February 15 through July 1 of each year. There is no specification on the period of time for which ice patrol costs are collected. Article 6 simply states that the "Government of the United States of America will furnish annually ... a statement of the cost of operating the Ice Patrol." The Agreement provides that if countries that are not a party to the financing Agreement are benefiting to an appreciable degree from the services of the Ice Patrol, the United States Government shall inform the other parties and if there are no objections, extend an invitation to the benefiting

passing through the regions of icebergs guarded by the Ice Patrol." Separate paragraphs of Regulation 6 include provisions for terminating participation or altering the provisions of Regulations 5 and 6 by the contributing governments, and require a review of the arrangements relating to contributions to the cost of the services at intervals not exceeding three years with the managing Government (here the United States) initiating that review. Other regulations address speed near ice and routing (which requires Contracting Governments to induce ships to avoid, as far as practicable, the fishing banks of Newfoundland north of latitude 43°N and to pass outside of regions known or believed to be endangered by ice.)

non-party governments to accept the Agreement and share in the support of the Ice Patrol.

Section 738 of Title 46 United States Code provides the basic authority for the President to conclude international agreements for the conduct of an ice patrol and related issues. It authorizes the President to include in such agreements a provision for payment to the United States by the countries concerned of their proportionate share of the expense of the service, or for the United States to contribute its proportionate share should it be agreed that another country maintains the patrol. As currently structured, any cost reimbursement receipts are deposited in the U.S. Treasury and are not credited against the Coast Guard's operating budget. By default, it is assumed that the Coast Guard is the U.S. agency that is responsible for paying the United States share of the cost.

3.1.3.2 Benefiting Tonnage and Proportionate Cost Shares

The tonnage data used to compute the proportionate shares are obtained from the United States Customs Service and from Canadian Customs. The tonnage data used is the total for all Canadian Atlantic Coast ports and all United States Atlantic and Gulf Coast ports. The presumption is that all tonnage to or from those ports used the North Atlantic shipping lanes though the Ice Patrol's area of responsibility. Individual countries may then request tonnage exceptions by submitting a list of individual voyages that did not meet the criteria. Over the 1987-1992 period, the average tonnage computed during the February 15 - July 1 period was 154,923,413 GRT, and the average exceptions was 4,902,659 GRT. The average benefiting tonnage was 150,020754 GRT. During this time period, a total of 96 countries benefited from International Ice Patrol Services while a maximum of 20 countries had agreed to share the costs of the Ice Patrol.

Detailed tonnage and exception data are included in Annex D (Appendix I) for the 1987-1992 International Ice Patrol years. Data for 1993 and 1994 are not yet available. The Department of State contracts with the Bureau of Census to compile the data. The adjusted GRT tonnage data for the governments that have accepted the financial Agreement are included in Table 8.

Table 8 clearly indicates the impact of Liberia's withdrawal from the Agreement. With an adjusted tonnage over 20 million GRT, Liberia alone represents approximately 13% of the total benefiting tonnage. The final comparison in Table 8 illustrates the impact of the non-contributing governments. With Liberia's withdrawal, the remaining 19 countries represent 53% of the total benefiting tonnage in 1992. Almost half of the benefiting tonnage is not contributing to the support of the International Ice Patrol. Besides Liberia, the "most" benefiting non-contributors are Bahamas (9,565,175 GRT), Cyprus (9,492,168 GRT), Malta (5,815,641 GRT), Singapore (3,422,174 GRT), and Russia (2,894,191 GRT). These countries have benefiting tonnage greater than ten of the contributing governments.

The total costs provided by the United States Coast Guard for the operation of the International Ice Patrol are included in Table 9 with the proportionate cost shares for 1987-1992. Note that the total costs increased significantly for the 1991 and 1992 seasons due to the heavy ice years and the increased length of the season. In addition to the longer ice season, cost shares have also increased between 1990 and 1991 due to the withdrawal of Liberia. Five countries (Norway, Greece, United States, Panama, and United Kingdom) have cost shares covering 67% of the cost of operation of the International Ice Patrol.

3.1.3.3 Cost Reimbursement

The Coast Guard typically provides a cost breakdown for the International Ice Patrol to the Department of State in the December-January time frame immediately following the ice season. The Coast Guard costs are provided to the Bureau of the Census for allocation by contributing government based on benefiting tonnage. The tonnage data has a much greater lag time, requiring input from both United States and Canadian Customs. In addition, there is an exchange of data with the contributing governments to provide an opportunity for them to identify exceptions. Using the recorded tonnage and exceptions approved by the

Table 8: Adjusted Benefiting GRT Data, 1987-1992, for Contributing Governments.

Country	1987	1988	1989	1990	1991	1992
Norway	2,205,937	2,813,364	7,539,665	13,619,982	13,356,129	11,944,383
Greece	10,206,185	9,946,222	10,144,793	9,439,085	10,186,163	10,813,944
United States	8,060,868	9,811,133	11,600,224	13,346,977	14,278,116	10,534,132
Panama	13,229,182	14,210,070	13,129,388	10,775,425	8,878,526	10,312,051
United Kingdom	10,743,752	9,216,308	8,092,610	8,292,847	9,466,788	7,798,978
Poland	2,700,619	3,534,546	2,523,029	2,348,903	2,225,294	5,196,156
Italy	4,257,331	7,158,378	4,187,118	5,863,796	6,320,707	3,990,145
(West) Germany	5,121,241	3,562,192	3,019,752	3,519,725	4,029,981	3,693,809
Denmark	1,520,652	2,465,881	3,233,874	4,178,712	2,976,476	3,271,960
Spain	1,746,472	3,148,306	2,587,767	2,329,873	2,161,626	1,541,529
Sweden	1,857,762	1,543,881	1,955,172	2,380,034	2,682,225	1,473,158
Netherlands	2,453,740	1,749,447	1,149,343	829,483	771,113	1,297,459
Yugoslavia	1,765,286	2,430,049	1,362,516	3,070,766	3,237,134	1,035,529
Japan	3,648,380	3,564,478	3,311,127	2,070,639	1,943,286	1,028,139
France	1,117,116	1,403,390	1,289,670	1,388,019	1,145,071	878,937
Belgium	2,670,691	1,655,756	1,717,867	2,240,161	2,197,431	875,299
Israel	820,896	841,315	916,921	805,272	854,329	861,052
Finland	114,511	200,073	292,196	270,289	387,795	248,290
Canada	1,588,249	1,820,589	382,401	88,179	44,504	77,035
Liberia	6,634,118	24,947,411	22,339,285	22,519,237	0	0
Total Contributing	82,462,988	106,022,789	100,774,718	109,377,404	87,142,694	76,871,985
Total all governments	139,837,546	153,608,227	150,261,988	157,115,873	154,545,975	144,754,915
% by Contributing	59.0%	69.0%	67.1%	69.6%	56.4%	53.1%

Table 9: Proportionate Cost Shares for Contributing Governments, 1987-1992.

Country	1987	1988	1989	1990	1991	1992
USCG IIP Total Cost ($US)	*$1,738,600*	*$1,850,900*	*$2,209,300*	*$1,682,100*	*$3,302,200*	*$3,318,800*
Norway	46,509	49,114	165,293	209,460	506,119	515,676
Greece	215,181	173,637	222,406	145,162	385,996	466,871
United States	169,950	171,279	254,314	205,261	541,057	454,791
Panama	278,916	248,073	287,838	165,714	336,444	445,203
United Kingdom	226,515	160,894	177,416	127,535	358,736	336,706
Poland	56,938	61,705	55,313	36,123	84,236	224,334
Italy	89,759	124,968	91,795	90,179	239,518	172,267
(West) Germany	107,973	62,187	66,202	54,129	152,713	159,473
Denmark	32,061	43,048	70,897	64,264	112,791	141,261
Spain	36,822	54,962	56,732	35,831	81,913	66,553
Sweden	39,168	26,952	42,864	36,602	101,641	63,601
Netherlands	51,733	30,541	25,197	12,757	29,221	56,015
Japan	76,920	62,227	72,590	31,844	73,639	44,388
Yugoslavia	37,218	42,423	29,871	47,225	122,669	44,707
France	23,553	24,500	28,274	21,346	43,392	37,946
Belgium	56,307	28,905	37,661	34,451	83,270	37,789
Israel	17,307	14,687	20,102	12,384	32,374	37,174
Finland	2,414	3,493	6,406	4,157	14,695	10,719
Canada	33,486	31,783	8,383	1,356	1,686	3,326
Liberia	139,870	435,521	489,748	346,320	0	0
Total ($US)	*$1,738,600*	*$1,850,900*	*$2,209,300*	*$1,682,100*	*$3,302,200*	*$3,318,800*

Department of State, the Bureau of the Census computes the proportionate shares for the contributing governments and then computes the respective cost shares as above. The complete analysis is provided to the Department of State. To illustrate the scope of the delay, the 1992 tonnage data was provided to Department of State in January, 1995, and the 1991 tonnage data was provided in April, 1994. The 1987 and 1988 data were provided in March, 1989 and March 1990, respectively. It appears that the data processing has improved significantly and that the 1993 data are nearly ready.

When the Office of Maritime and Land Support in the Department of State receives these data, the proportionate cost shares are included in a diplomatic note to the contributing governments. In most cases, the governments receiving these cost assessments include them in their next budget. Not only is there a significant delay in "billing" the beneficiaries, but there is an additional delay associated with the budgeting required in the several countries before payment can be made. Because of this budgeting process, it is important that the payment/billing backlog be managed so that the expected payment is not overwhelming for the contributing governments.

Table 10 summarizes the status of reimbursements in the 1985-1992 period showing the amount billed and the percentage compliance. Annex D (Appendix IV) contains similar data for the entire period from 1977-1992 and includes amounts billed, amounts paid, amounts due, and payment compliance. In reviewing the Table 10 data, note that the 1991 and 1992 bills have only recently been distributed, and both the 1990 and 1991 bills have been adjusted to account for a computational error. Overall, most of the countries provide complete and timely payment. For the five year period from 1985 through 1989, the following countries paid 100% of their assessment: Belgium, Denmark, Finland, Germany, Greece, Japan, Netherlands, Norway, Sweden, and the United Kingdom. Of the remaining countries, Canada, Italy, Poland, and Spain have missed one year's assessment. During this period, France missed two payments, but has paid for 1991. Except for 1991, Israel has not made any payments since 1982. However, Israel has recently agreed to make payment for all outstanding assessments. Beginning with the 1987 assessment, Liberia has not made any payments. In 1991, Liberia formally withdrew from the financing Agreement. Yugoslavia, like Liberia has experienced significant political turmoil. Payments have not been made for the 1988 ice season and beyond. It is not clear which state is the successor state. Panama's payment compliance record has been mixed. On the average, Panama appears to be paying about two-thirds of the assessed amount.

The totals billed and collected and the impact on the cost recovery by the United States is partly illustrated in Table 11.

Clearly, Table 11 indicates that the United States has had to pay significantly much more than its share. Again, we must exclude 1990-1992 in this comparison because most payments have not been made and some data is incomplete. In 1987-1989, the largest source of non-payment was Liberia. In addition, Panama's partial payments in those years has not been completed and a significant balance remains. In 1988, non-payment by France, Italy, Spain, and Yugoslavia led to a significant shortfall. In 1987, Panama's partial payment was the major factor in the cost reimbursement shortfall.

With Liberia's withdrawal, the cost attributed to Liberia's tonnage will be proportionately distributed to the other contributing nations. Until the political situation in Yugoslavia is resolved, it is unlikely that any of that country's cost share will be recovered. It is not known why Panama is not making full payments. With Israel's agreement to provide reimbursement, it appears that the prospects are good for sustaining a relatively high percentage compliance with cost reimbursement. For example, using 1989 data, excluding Liberia, and considering non-payment by Yugoslavia and 27% of Panama, the cost reimbursement would be almost 94% (including the United States share). The unrecovered portion would be approximately $108,000. Note that Table 11 indicates actual re-

Table 10: Cost Shares Billed and Payment Compliance for Contributing Governments, 1985-1992.

Country		1992	1991	1990	1989	1988	1987	1986	1985
Belgium	*Billed ($US)*	37,789	82,370	34,451	37,662	29,806	56,307	37,286	63,515
	Compliance	0.00%	0.00%	0.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Canada	*Billed ($US)*	3,326	1,686	1,356	8,384	31,784	33,486	15,373	32,316
	Compliance	0.00%	0.00%	99.34%	0.00%	100.00%	100.00%	100.00%	100.00%
Denmark	*Billed ($US)*	141,261	112,791	64,264	70,896	43,048	32,061	19,728	45,559
	Compliance	0.00%	98.90%	98.87%	100.00%	100.00%	100.00%	100.00%	100.00%
Finland	*Billed ($US)*	10,719	14,695	4,157	6,405	3,493	2,414	6,086	21,083
	Compliance	0.00%	0.00%	99.35%	100.00%	100.00%	100.00%	100.00%	100.00%
France	*Billed ($US)*	37,946	43,392	21,346	28,275	24,500	23,533	18,739	35,317
	Compliance	0.00%	98.90%	0.00%	0.00%	0.00%	100.00%	100.00%	100.00%
Germany	*Billed ($US)*	159,473	152,713	54,129	66,202	62,187	107,973	54,617	81,947
	Compliance	0.00%	98.32%	99.36%	100.00%	100.00%	100.00%	100.00%	100.00%
Greece	*Billed ($US)*	466,871	385,996	145,162	222,406	173,637	215,181	145,344	247,891
	Compliance	0.00%	98.90%	99.36%	100.00%	100.00%	100.00%	100.00%	100.00%
Israel	*Billed ($US)*	37,174	32,374	12,384	20,102	14,687	17,307	11,992	20,493
	Compliance	0.00%	98.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Italy	*Billed ($US)*	172,261	239,518	90,179	91,794	124,967	89,759	67,877	95,037
	Compliance	0.00%	98.90%	99.36%	100.00%	0.00%	100.00%	100.00%	100.00%
Japan	*Billed ($US)*	44,388	73,639	31,844	72,591	62,227	76,920	44,591	66,100
	Compliance	0.00%	98.58%	99.36%	100.00%	100.00%	100.00%	100.00%	100.00%
Liberia	*Billed ($US)*	Withdrew	Withdrew	346,320	489,747	435,520	139,870	373,449	592,823
	Compliance			0.00%	0.00%	0.00%	0.00%	100.00%	80.51%
Netherlands	*Billed ($US)*	56,015	29,221	12,757	25,297	30,542	51,733	29,259	58,528
	Compliance	0.00%	98.90%	99.36%	100.00%	100.00%	100.00%	100.00%	100.00%
Norway	*Billed ($US)*	515,676	506,119	209,460	165,293	49,114	46,509	54,167	169,215
	Compliance	0.00%	0.00%	99.36%	100.00%	100.00%	100.00%	100.00%	100.00%
Panama	*Billed ($US)*	445,203	336,444	165,724	287,839	248,072	278,916	196,914	287,369
	Compliance	0.00%	65.54%	99.35%	73.04%	44.44%	20.02%	100.00%	0.00%
Poland	*Billed ($US)*	224,334	84,326	36,123	55,312	61,705	56,938	30,657	58,811
	Compliance	0.00%	0.00%	99.35%	0.00%	100.00%	100.00%	100.00%	100.00%
Spain	*Billed ($US)*	66,553	81,913	35,831	56,733	54,962	36,822	33,385	67,608
	Compliance	0.00%	0.00%	0.00%	100.00%	0.00%	100.00%	100.00%	100.00%
Sweden	*Billed ($US)*	63,601	101,641	36,602	42,863	26,953	39,168	27,477	49,833
	Compliance	0.00%	98.90%	99.36%	100.00%	100.00%	100.00%	100.00%	100.00%
United Kingdom	*Billed ($US)*	336,706	358,736	127,535	177,416	160,895	226,515	153,486	253,392
	Compliance	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Yugoslavia	*Billed ($US)*	44,707	122,669	47,225	29,870	42,423	37,218	0	31,108
	Compliance	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%		100.00%

Table 11: IIP Cost Reimbursement Summary, 1985-1992.

($US)	1992	1991	1990	1989	1988	1987	1986	1985
Total Billed	$3,318,794	$3,302,200	$1,682,110	$2,209,400	$1,850,900	$1,738,600	$1,448,400	$2,480,101
Total Collected	$791,497	$2,227,593	$1,178,764	$1,470,843	$1,140,986	$1,358,351	$844,110	$2,056,668
IIP Cost	$3,318,800	$3,302,200	$1,682,100	$2,209,300	$1,850,900	$1,738,600	$1,448,400	$2,480,101
US Share	$454,791	$541,057	$205,261	$254,314	$171,278	$169,950	$106,038	$202,156
US Paid	$2,982,094	$1,565,664	$708,597	$992,770	$881,192	$550,199	$710,328	$625,569

imbursement to be lower because some governments have not yet submitted their payments.

The existing reimbursement system relies on flag state payment. An alternative approach could be structured to collect payment directly from shippers based on actual tonnage. At present shipping levels and IIP costs, the cost would be approximately $.03 per GRT.

3.1.4 Mission Effectiveness

3.1.4.1 Measures of Effectiveness

The existing measure of effectiveness for the IIP program is the casualty rate presented in section 3.1.1.1. The Program Description acknowledges the weakness of this measure. In fact, the area of application is not defined. Presumably, it would apply outside of the LAKI. Mission performance measures of effectiveness are discussed in greater detail in section 9.0 of Annex A. Included is an analysis of the proposed MOEs developed at a Measures of Effectiveness Workshop held in March, 1994. The proposed measures included:

M.1 Difference between the predicted LAKI and the actual LAKI normalized by the length of the limits.

M.2 Number of icebergs reported outside of the LAKI.

M.3 Number of ship sighting reports.

M.4 Number of calls for the facsimile chart.

M.5 Number of ice information sources obtained.

M.6 Number of times broadcast objectives were not met or the difference in time between the actual time to broadcast and the standard time specified.

M.7 Customer satisfaction measure: conduct valid user surveys at regular intervals.

M.8 Cost efficiency: total cost to perform mission/normalization factor (to account for season severity)

Measures M.3, M.4, and M.5 are externally generated and are uncontrollable with respect to IIP activities. Measures M.6 and M.8 are efficiency measures. Measure M.7, while valuable, is generally not available on a continuous basis to characterize effectiveness. Measure M.2 is the measure of closeness to the desired goal of zero icebergs being located outside of the LAKI. It seems that it should be related somehow to the number of opportunities for icebergs to be outside of the LAKI. With such a base, it could be a system effectiveness measure, although the relative occurrence has historically been very low. It may not be a sufficient measure for management improvement purposes. Measure M.1 is a modeling effectiveness measure. It would measure how well the models predicted the LAKI and would be very useful in assessing confidence levels for the LAKI prediction.

The development of MOEs is beyond the scope of this study and should be included in the full Mission Analysis. For purposes of this COEA, the effectiveness provided by the present system was established as the standard. Comparisons of alternatives will be with respect to present IIP performance and the cost differential will be assessed to evaluate the alternative.

3.1.4.2 User Satisfaction

One proposed measure of effectiveness is periodic user surveys to determine their satisfaction with the IIP service. In May, 1993, IIP sent a survey to 202 shipping companies whose vessels submitted ice reports during the 1992 ice season. The questionnaire included seven open-ended questions primarily regarding the use of IIP products. As of November, 1993, only 26 companies had responded (13% response rate). Of the respondents, 84% always use IIP products with nearly half using the bulletin and facsimile chart. A quarter of the respondents never use the fax chart, but almost half use the bulletin to draw the limits. About 76% said the IIP products meet their need (the other 24% did not respond). Half of the respondents do alter their course based on ice warnings. Most comments provided were positive. Negative comments involved NAVTEX and a need for more

detail (iceberg positions). This small survey suggests that IIP is performing a valuable service and doing a good job at it, but a more extensive survey is required.

The Phase I study results concluded that a minor effort should be placed on developing a new user survey. A survey was designed that will capture user satisfaction issues as well as identify which products are being used and what effect they may have on shipping behavior. This will be a first step in conducting an assessment that seeks to get at how much change are the mariners willing to make to avoid icebergs. In the 1993 survey, only half of the respondents indicated that they alter course in response to IIP products. The survey was distributed via INMARSAT in early May, 1995 to all vessels in the North Atlantic. A repeat broadcast is planned for June, 1995. Recipients were requested to respond by fax or mail. A copy of the survey in the form that it should have been received by all ships in the North Atlantic is included in Appendix 1.

3.1.4.3 Other User Issues

The question has been raised as to how the existence of the IIP may affect insurance coverage. Appendix 2 contains some surprising results. Mr. John Moloney, General Secretary of Lloyds Underwriters Association canvassed all of the affiliated Lloyd's activities and has found no one who uses or monitors the IIP services. It has been suggested that writing insurance policies that require the ship to monitor all warnings has led to a lack of interest in IIP by the insurers. That there is a fundamental lack of understanding among insurers is evidenced by a fax from Michael Shelly who indicated that they would not insure craft crossing the Atlantic on a northerly route between November and March. Of course, from an iceberg perspective, that is probably the optimal time for such a crossing.

As for use of the information and routing, Mr. David Rail, Customer Service Manager for WNI Oceanroutes reported that they use IIP ice information continuously for routing ships (1200-1500 per year) in the North Atlantic. He estimated that a more conservative routing in the absence of IIP information would cost their clients an additional $3-4 million per year as well as increase the perceived risk of encountering unexpected ice.

3.2 TECHNOLOGY

The technology that applies to the IIP involves the systems and procedures that transform the collected environmental and sighting data into information characterizing the estimated positions of icebergs. In the following sections the baseline description of present systems processing and the state of knowledge concerning the drift and deterioration models is presented. More detailed descriptions are included in Annexes A, G, H, and L.

3.2.1 Information Processing

Information acquisition, processing and distribution for the IIP is covered in detail in section 4 of Annex A and in Annex L. The use of modeling technology has enabled the IIP to improve the quality of its product while simultaneously reducing the resources required to accomplish the mission.

The IIP accomplishes its mission by acquiring data and information about the location and extent of ice and most recent environmental conditions in its area of operation, processing those inputs to develop relevant information regarding the threat of ice to the trans-Atlantic shipping lanes, and distributing that information to interested mariners. A key element in this process is the use of an iceberg Data Management and Prediction System (DMPS) that is capable of managing these data within the IIP area of operation from 40°N to 52°N latitude and 39°W to 57°W longitude. The primary products generated by IIP include ice bulletins, INMARSAT, and NAVTEX messages that contain the 0000Z and 1200Z Limits of All Known Ice, a facsimile chart with the 1200Z ice limits that is transmitted at 1600Z and 1810Z, and safety messages to warn shipping of icebergs sighted outside of the published ice limits. The key processes are illustrated in Figure 6.

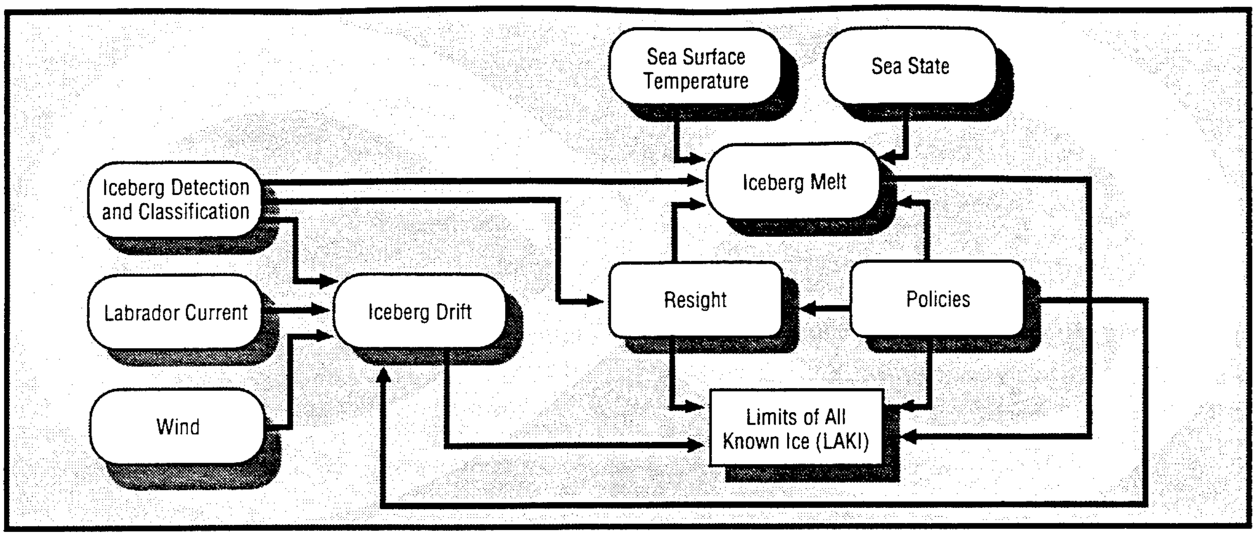

Figure 6: IIP Process Influence Diagram.

In processing iceberg data, the IIP conducts *analysis* runs and *prognosis* runs. The analysis runs use the latest environmental data. In an analysis run, both the drift model and the deterioration model are applied to each iceberg and radar target on plot. The resulting analysis run is the basis for the deletion of icebergs from the plot. The closest analysis run to the time of sightings is the basis for the resight analysis where reported sightings are identified with predicted positions of icebergs and radar targets and new sightings that can not be identified with an existing iceberg or radar target are added to the plot. The resulting set of icebergs and radar targets is the basis for the prognosis run. A prognosis run is used to develop the 0000Z and 1200Z products. Note that the prognosis run only applies the drift model and does not include any iceberg deterioration beyond the time of the last analysis run.

A detailed data and information process flow is illustrated in Figure 7.

The primary source of environmental data is the U.S. Navy Fleet Numerical Meteorology and Oceanography Center (FNMOC). IIP receives surface wind, wave height, and wave period data twice a day and sea surface temperature (SST) data once each day. These data are received in digital form via INTERNET. In addition, real time current data from IIP deployed drift buoys is incorporated on a regular basis to temporarily modify the (geostrophic) Labrador Current data file. IIP receives daily buoy positions from Service ARGOS and computes the drift on a weekly basis. The "real time" current estimates modify the geostrophic currents for a two week period following their collection. The surface wind, iceberg position, estimated iceberg size, real time current, and geostrophic current are used in the iceberg drift model. A separate iceberg deterioration model uses the iceberg position, iceberg size, SST, and wave height and period data. The effective operation of IIP requires that these environmental data be received in a timely fashion with high accuracy and reliability.

The IIP effectively captures available data on iceberg and radar target sightings from other organizations as well as from IIP Ice Reconnaissance Detachment flights. All iceberg sighting data received from Ice Centre Environment Canada (ICEC), including BAPS data, AES surveillance, Atlantic Airways surveillance, and ship sighting reports submitted to ICEC, are transmitted to IIP in digital form via INTERNET. Ship sighting reports submitted directly to IIP must be coded in order to be used in the iceberg Data Management and Prediction System (DMPS). Because of the importance of high quality information along the Limits of All Known Ice (LAKI), the IIP Ice Reconnaissance Detachment (ICERECDET) conducts biweekly surveillance flights from St. John's, New-

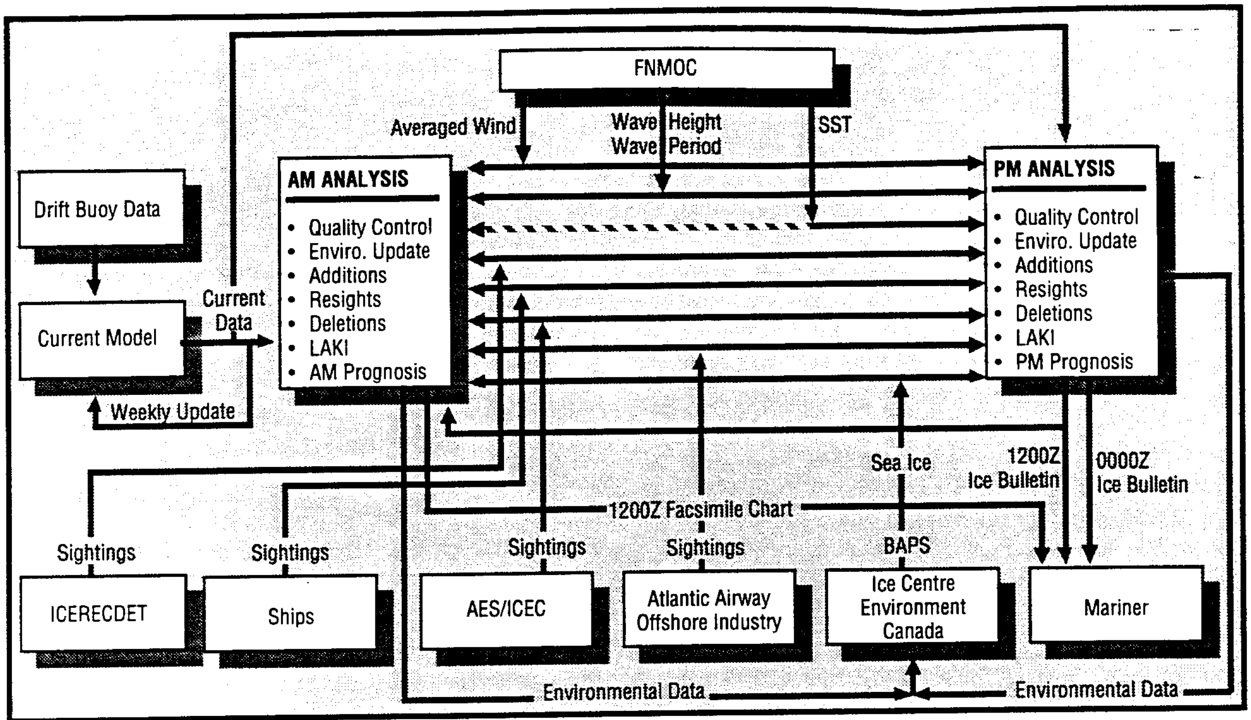

Figure 7: IIP Data and Information Process Chart.

foundland that concentrate on providing information on icebergs and radar targets in the area defining the LAKI. The most labor intensive aspect of data acquisition is sighting data obtained on ICERECDET flights. The approximate positions of iceberg/radar target sightings are transferred from the SLAR dry film to a message format that is sent as a digital file to IIP. The sighting positions are estimated from the INS position of the aircraft. Error sources include INS error, that varies as the flight progresses, and the estimation error in transcribing from the dry film. Because the iceberg drift model is very sensitive to iceberg positions, it is imperative that the data acquisition process minimize the chances of errors in position.

Because of quality assurance requirements, all incoming data files must be reviewed before they are accepted for use in the system. Under the existing product structure for ice bulletins and the ice chart, there is an approximate work window of 2-3 hours for accomplishing the data check, data entry, and processing. At best, processing time is linear with the number of icebergs and targets in the system. The system should be designed to handle a maximum load of approximately 1500 icebergs and radar targets. With the existing software, data processing is interactive and requires the operator to evaluate each reported sighting to determine whether it is a new sighting or a resighting of an existing system entry (iceberg or radar target). In the existing practice, some new sightings (typically above a certain latitude) are never entered because of the lack of available processing time. The processing system must be able to respond quickly enough to permit all sightings to be reviewed and entered as appropriate.

Iceberg Reconnaissance Messages and iceberg sighting reports may be received at any time during the day. The sightings may be considered for addition to the DMPS twice daily when the DWO conducts the morning (AM) analysis or the afternoon (PM) analysis. At the time of the AM analysis, the DWO has on hand the 0000Z and 1200Z prognosis runs showing the predicted positions and predicted deterioration (as of the last analysis run) of icebergs and radar targets at those times. These prognosis runs were developed as part of the previous PM analysis. The AM analysis is typically conducted in the 1200-1400Z time frame. At

the time of the PM analysis, the DWO has on hand the 1200Z (today) and 0000Z (tomorrow) prognosis runs showing the predicted positions of icebergs and radar targets at those times and predicted deterioration as of the time of the last analysis run. These prognosis runs were developed as part of the previous AM analysis. The PM analysis is typically conducted in the 1900-2100Z time frame.

The reported sightings may be new (previously undetected) icebergs or sightings of previously reported icebergs (resights). If a sighting is determined to not be a resighting, then it is added to the DMPS as a new iceberg/radar target. The Standing Orders for IIP Operations Center Duty Personnel directs the DWO to use the closest available analysis run file to the sighting time. It further directs that sighting messages be entered in chronological order and notes that multiple reports may resight the same iceberg. The primary criteria for considering as resights are those sightings which (a) overlap, within twice the system error (maximum 60 nm), of icebergs or radar targets already being modeled, and (b) agree, within system error (1 size category), with deterioration information. If a sighted iceberg is designated as a resight of a radar target, the modeled entity is regarded as an iceberg with the reported properties; if a radar target is designated as a resight of an iceberg, the modeled entity continues as an iceberg with only the location information changed by the resight.

The INTERGRAPH computer system and DMPS provide a graphical display which facilitates the resight analysis by the DWO. Specifically, the DMPS displays the icebergs on plot with their reported size, error circle, melt state, and drift track, and simultaneously displays the new sightings. Using an analysis run closest in time to the reported sighting, the DWO compares the existing icebergs and radar targets with the new sightings using the resight criteria to determine whether a particular sighting is a resight or a new iceberg or radar target. There is a significant amount of "art" involved in this process. Numerous other factors such as bathymetry and areas of highly variable currents may impact the resight decision. Additionally, extra attention is given to those icebergs and sightings near the LAKI. After completing the resight analysis, the new positions of icebergs/radar targets have been merged into the DMPS. For icebergs and radar targets outside of the IIP area of operation, particularly below 40°N, special manual procedures are specified.

An analysis run is conducted to incorporate the latest sighting and environmental data. This provides a graphical display of the estimated positions of icebergs and radar targets at the designated run time along with the previous LAKI. Using this display, the DWO can delete icebergs and radar targets that satisfy the deletion criteria. Two factors apply to deletion: modeled deterioration, and ICERECDET reconnaissance. Radar targets outside of the LAKI and limit setting bergs within 60 nm of the LAKI may be deleted when modeled deterioration exceeds 150%; icebergs and radar targets more than 60 nm inside the LAKI, may be deleted when modeled deterioration exceeds 125%. Radar targets outside of the LAKI and limit setting bergs within 60 nm of the LAKI may be deleted when visual search or 200% SLAR coverage with wave heights less than 6 feet finds nothing; icebergs and radar targets more than 60 nm inside the LAKI, may be deleted when visual search or 100% SLAR coverage with wave heights less than 6 feet finds nothing. When deletion of an iceberg results in a significant change in the LAKI, CIIP must review and approve the deletion.

The Ice Patrol Bulletins are transmitted at 0000Z and 1200Z daily. They contain the estimated Limits of All Known Ice, the estimated limit of sea ice (based on latest information from ICEC), positions of southern and eastern most bergs, positions of growlers, positions of radar targets, and the area of many icebergs. The Bulletins are based on conducting a prognosis run (drift only) from the latest analysis run. The predicted positions of the icebergs are used to estimate the LAKI. The INMARSAT and NAVTEX messages are prepared at the same time as the ice bulletins using the estimated LAKI.

The icebergs that remain after the deletion analysis are used to set the new Limits of All Known Ice

for each prognosis run. The general guidelines are that the LAKI should be constructed so that a convex polygon defined by no more than seven points encloses all icebergs and their error circles. Normally, the polygon is tangent to the error circles of the limit setting icebergs. A general guideline is that the LAKI enclose an area no larger than is necessary. Note that radar targets may not be used to set the limits. Those radar targets outside of the LAKI and those between the boundary of the LAKI and the Area of Many Icebergs are included in the ice bulletin and shown on the facsimile chart. Additional criteria require the use of easily plotted points.

The core processing system is an INTERGRAPH computer system with high resolution graphical displays using a modified VAX computer as the main processor. This system operates the iceberg Data Management and Prediction System (DMPS). The system was placed into service for the 1993 ice season. The DMPS was developed from the iceBerg Analysis and Prediction System (BAPS) which was developed for ICEC. In addition to the INTERGRAPH, a system of PCs and the use of the Coast Guard Standard Terminal provide additional support for processing.

The display design is very functional and conveys a significant amount of information to the DWO in a meaningful way. Two screens are active: one provides the messages and commands/menus, while the other provides a display of the region of interest. A mouse and mousepad provide the mechanism for selecting functions. The graphical display screen is characterized by icons and color displays to convey critical information. There is a zoom capability and the ability to selectively display various characteristics to minimize the visual interference. In addition, data stores with entity characteristics can be displayed to facilitate analysis.

The major problem with the existing system is the processor speed and no ability to accomplish multiple processing. Otherwise, the system appears to be very functional. The current system operation includes frequent backups of working documents. Standby products are maintained in case there are system problems that would stop its normal functioning. Working copies of the system file are maintained for use on a PC if necessary. During 1994, there have been three system failures that required PC processing. A maintenance contract is in effect which is supposed to result in rapid repairs. However, it is becoming more difficult to find qualified vendors to support system maintenance because of the rapidly changing technology. As noted in section 2.3.3.2, ICEC is developing the ISIS system which will absorb BAPS and eliminate their INTERGRAPH system. That change, scheduled for 1996, will impact the software support that DMPS receives from ICEC.

3.2.2 Iceberg Deterioration Model

The iceberg deterioration model used by IIP, based on the work of White, Spaulding, and Gominho (1980), was completed and initially tested in 1983 (Anderson, 1983). The model considers four forms of deterioration: insolation (sun heating), buoyant convection (vertical circulation of the water), wind forced convection (drift movement through the water), and wave induced deterioration (wave washing of the subaerial surface). Four equations determine the melt due to each of these processes which are additive. Input data include: iceberg position; iceberg size; sea surface temperature; wave height; and wave period. Progressive deterioration of the iceberg is quantified by its waterline "length" by definition. There are four size categories: growler, small, medium, and large with no upper limit. The model used by IIP does not include deterioration due to calving of overhanging ice slabs (Anderson, 1983). Deterioration due to calving depends on the thickness of the overhanging slab which is not generally available. Not including the deterioration due to calving underestimates the degree of deterioration in a given time period. The model and its evaluation are addressed in greater detail in section 6 of Annex A and in Annex G.

The model equations applied with a 6' wave height, 10 sec wave period, and 25 cm/sec relative velocity (SST unknown) result in 84 percent of the iceberg's deterioration being attributable to wave induced melting; approximately 14 percent

due to wind drift of the iceberg relative to the water bathing it; and less than 2 percent related to sun heating and vertical circulation along the iceberg's submerged surface.

In the application of the model, the maximum waterline length for the size category reported is used initially. If an iceberg is resighted, the waterline length is set to the maximum for the size reported in the resighting eliminating any deterioration which may have occurred if the resighting indicates the same or larger size. Icebergs for which no size category is reported are assumed to be medium icebergs. Note that the only melting component that depends on the size of the iceberg (waterline length) is wind forced convection melting. Thus, deterioration can be computed after the waterline length has decreased to zero. Icebergs are removed from the model when 125 percent of their original waterline length has been melted if they remain within the bounds of all known ice, unless they are limit setting icebergs for the region of all known ice in which case they are retained by the deterioration model until 150 percent of their waterline length has been melted.

Anderson (1983) conducted an initial mathematical analysis of the model: with all other parameters held constant, a 100 meter length iceberg took 179 days to melt in -1°C water compared with 20.5 days in 3°C water. Anderson concluded that input data errors of 1°C variance from actual sea surface temperatures in this temperature range can produce melt errors on the order of 40 days for this 100 meter berg length. These results suggest that the sea surface temperature is the most critical parameter. However, other parameters were not examined and the results only hold in the range of SST considered in the analysis.

Several studies by Venkatesh, El-Tahan, and Mitten (1985), Venkatesh (1986), and El-Tahan, Venkatesh, and El-Tahan (1987) compared model performance with observed deterioration of several icebergs using observed oceanographic and meteorological data. They also developed refined size estimates. Using these data, they found good agreement between the model results and actual deterioration.

In 1987 the IIP conducted a deterioration study using 6 icebergs, observed and tracked by a surface vessel (Hanson, 1987). The time of observation on each iceberg ranged from 2.1 days to 6.3 days. The objectives of this study were to compare iceberg deterioration predictions derived from observed environmental to predictions using system (FNMOC) data. FNMOC SST data were an average of 1.3°C colder than that actually observed, the wave heights averaged 0.9 meters higher than observed, and the periods were on average 4.6 seconds greater than observed. The 6 iceberg cluster averaged 379 cm/day melt rate of their waterline length using observed wave erosion values, while using the system operational data provided by FNMOC produced a melt rate on average of 531 cm/day. The overestimation of the predicted wave height was identified as the primary cause of the significant overestimation of the melt rate, even though the predicted temperatures also averaged 1.3°C colder, which would tend to slow the melt rate. The actual observed iceberg length changes as compared with the model predictions made as part of this test were inconclusive due to the time constraints (i.e., 2 to 6 days.)

The various studies suggest that the iceberg deterioration model is a reasonable approximation of the deterioration process when observed environmental data is used, although no iceberg has been observed to the point of 100% melt. The 1987 IIP study (Hanson, 1987) identified significant differences between the FNMOC data and observed data. In 1988, all FNMOC environmental products were improved and the new data was used by IIP (Hanson, 1988). The new values for SST, sea height, and sea period are reportedly in agreement with observed values, although no validation experiments have been reported. None of the IIP analyses or reports indicates that a complete sensitivity analysis of the deterioration model has been conducted.

3.2.3 Iceberg Drift Model

The iceberg drift model used by IIP was completed and tested in 1980 (Mountain, 1980). Its format and use remains essentially the same to date. The fundamental drift model balance is be-

tween iceberg acceleration, air and water drag, the Coriolis acceleration and a sea surface slope term characterized by the mean ocean currents. The resulting differential equations are solved using a fourth-order Runge-Kutta analysis. Key input data include: iceberg location; iceberg size and shape; local wind; geostrophic (mean) current; and local currents from drift buoys. A more detailed treatment of the drift model is included in section 6 of Annex A and in Annex H.

Sensed or sighted icebergs are placed into one of four size categories (growler, small, medium, and large with no upper limit) which also automatically sets the mass and cross-sectional areas to the assumed characteristic values for the designated size category. One of two specific shape classifications, tabular or non-tabular, is also made when a visual sighting occurs. The model divides the subsurface shape of the iceberg into up to four draft layers, each with its own cross sectional size, depending on the iceberg classification. These areas are affected by the geostrophic ocean water current and a calculated depth and time dependent local wind driven current. A separate model is used to estimate the local wind driven current (Mooney, 1978, Mountain and Mooney, 1979). Icebergs whose size are unknown are assumed to be medium icebergs; those whose shape are unknown are assumed to be non-tabular icebergs. The model is operated every 12 hours using the most recent wind data, and drifts all icebergs on plot within the IIP operations area.

The IIP estimates that the initial position error is 5 nm regardless of sighting source and that model drift error increases linearly in 5 nautical mile per day increments for each 24 hours of additional model drift up to a maximum radius of 30 nautical miles. This maximum error of 30 nautical miles occurs after 5 days of drift. There is no increase in the maximum 30 nautical mile error estimate regardless of how long the iceberg is drifted within the IIP operations area. If an iceberg is resighted, the drift error calculation is restarted. Icebergs south of 40°N are assumed to have a daily drift error of 10 nm, accumulating over a period of 5 days to a maximum error of 55 nm.

The Iceberg Drift Model (Mountain, 1980) is comprised of a set of four differential equations that balance iceberg acceleration with the forces associated with air and water drag, the Coriolis acceleration and a sea surface slope term which describes the mean ocean currents The equations are solved using a fourth order Runge-Kutta method to obtain the east and north components of the iceberg drift from which the current speed and direction are computed. A critical factor in the equations is the velocity of the local wind driven current (Ekman current) at the four levels affecting the iceberg. The Ekman current components are obtained using a local wind driven current model (Mooney, 1978; Mountain and Mooney, 1979) that uses a 96 hour wind history. The IIP implementation uses eight 12 hour periods. The model from Mountain and Mooney (1979) involves two equations that are applied at each layer:

Initial model tests in 1980 used the tracks of 2 large tabular icebergs, a large pinnacle iceberg, and a freely drifting satellite-tracked buoy to compare the model performance with actual iceberg drift (Mountain, 1980). Results ranged from approximately a 5 nautical mile error for a 3 day drift to a constant 50-80 nautical mile error in the 25 day case. The assumed cause for the error in this test was stated to be inaccurate wind and current data inputs to the model.

In 1985, drift model tests were held in several different parts of the IIP operations area (Murphy and Anderson, 1985). Four case studies were performed using the drift model. In 3 of the 4 cases, the drift of the icebergs as depicted by the model using the system data had location errors ranging from 40 nautical miles after a 2.5 day drift, 30 nautical miles after a 3.3 day drift, and 45 nautical miles after a 4 day drift. These all exceed the standard drift error assumed by the IIP of a maximum of 30 nautical miles after a drift of 5 days. The 4th case study drift did remain well within the standard drift error and did not exceed an error of more than approximately 11 nautical miles over a 4 day drift. Better performance results from the model were realized when using the observed current and wind data for all four case studies,

instead of the automatically provided system data. (It is not known whether current from the local wind driven current was used at the different iceberg layers.) However, even with using real time data, in only one case was the predicted iceberg drift position error well within the accepted limits. Projecting a drift experiment such as this for a total period of 2 weeks, or 3 times as long as these case studies, suggests that the drift errors would continue to generate and become even larger.

Using the on scene wind and current data resulted in estimated positions closer to the actual iceberg position than using geostrophic currents and FNMOC winds. The limited experiments suggest that the structure of the model is sound and that its accuracy depends on the accuracy of the input data. The experiments did not isolate wind or current as the primary causal factor in generating errors. However, the case of one iceberg in Murphy and Anderson (1985) showed significant improvement by using observed currents with FNMOC winds. It should be noted that three of the cases in the Murphy and Anderson (1985) experiment were located in areas where significant reductions in geostrophic currents were instituted in 1989-90 (Murphy, Hanson, and Tuxhorn, 1990). It is also important to note that based on the trends in the various drift results, if the tests were continued beyond the 4 days, the model error would likely exceed the 30 nautical miles maximum drift error after a period of 10 days of predictions even with using the best on scene, observed data available.

3.3 OPERATIONS

Baseline operations describe the existing methods used by the IIP to detect, identify, and classify icebergs. This involves a description of the volume of the workload, sources for sightings, surveillance capabilities of systems that are used, including some details on the capabilities and functionality of the Coast Guard surveillance radars. A more detailed description is included in section 5 of Annex A and in Annexes C and J.

3.3.1 Iceberg and Radar Target Sightings

The IIP receives reports of icebergs and radar targets that may be icebergs from numerous sources including: IIP's aerial reconnaissance by its ICERECDET; the Canadian Atmospheric Environment Service (AES) aerial reconnaissance using its own aircraft and contract with Atlantic Airways; the Canadian Department of Fisheries and Oceans (DFO) aerial reconnaissance provided by the contracted Atlantic Airways; the National Ice Center (from a variety of DOD sources); ICEC (relays of ship sightings and BAPS); ships passing through the ice area, and other miscellaneous sources. The sightings received from those sources which were entered into the IIP models are summarized in Table 12. Note that these sightings include all icebergs, growlers, radar targets, and sightings identified as resights. The data are a measure of IIP model workload. The Atlantic Airways (both DFO and AES) and miscellaneous sightings are combined under "Other Air."

In interpreting the data, note that 1988 and 1989 were light ice years, 1990 and 1992 were heavy ice

Table 12: Iceberg and Radar Target Sightings Entered into IIP Models, 1988-1994.

	1988	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*
IIP	854	1,039	1,140	1,503	685	1,056	1,066
Other Air	131	269	408	393	1,493	3,908	3,407
AES	638	256	136	192	159	1,031	1,817
Ships	501	873	1,287	2,237	745	1,475	1,845
BAPS	0	205	4	0	82	556	1,311
DOD	15	256	171	35	3	0	0
Other	47	91	10	9	3	32	0
Total	***2,186***	***2,986***	***3,156***	***4,370***	***3,170***	***8,058***	***9,446***

years, and 1991, 1993, and 1994 were extreme ice years. Throughout the period, the data indicate that the IIP and ships have been relatively constant sources of sighting data. AES has accounted for an increase in sightings in the past two years, and within this period, Atlantic Air, under DFO contract, (included in "Other Air") has recently increased its activity and is a major factor in the increase in sightings in 1993 and 1994. With the introduction of the DMPS at IIP in 1993, it became feasible to receive iceberg position data directly from BAPS which accounts for another portion of the recent increase.

The key factor identifying a detection requirement is the number of icebergs below 48°N. These are compared with the number of sightings in Table 13 for 1988 through 1994. Note that these data do not include growlers, radar targets, or sightings that were resighted as icebergs.

Table 13: Icebergs S of 48°N Entered into IIP Models, 1988-1994.

	1988	1989	1990	1991	1992	1993	1994
Icebergs S of 48°N	187	301	793	1,974	876	1,753	1,765
Sightings	2,186	2,986	3,156	4,370	3,170	8,058	9,446

Icebergs either drift south of 48°N or are sighted south of 48°N. The sources of those icebergs and whether sighted or drifted south of 48°N are indicated in Table 14 for 1994. This provides some basis for identifying the current efforts supporting iceberg detection.

IIP was responsible for detecting 16%, Atlantic Air detected 37%, AES detected 21%, and ships detected 18% of the icebergs. Although the IIP was responsible for the smallest percentage, the particular icebergs were generally the ones of greatest importance—those in the vicinity of the Limits of All Known Ice. A detailed analysis of those icebergs that entered the region between the Area of Many Icebergs and the Limits of All Known Ice would provide stronger evidence on the criticality of the input from the several sources.

3.3.2 Visual and Remote Sensing Capabilities for Iceberg Detection

Ships transiting the area are requested to report the positions of ice and icebergs to CIIP or ICEC. Their sightings may be visual or radar. The observer's experience greatly affects the quality of the information provided.

ICEC uses a DeHavilland Dash-7 turboprop aircraft to cover the east coast of Newfoundland operating near the sea ice edge. It is equipped with side and top bubbles for visual observation and a real aperture CAL-200 SLAR. The aircraft is owned by Transport Canada and operated under contract with Bradley Air Services, Inc. Three Environment Canada Ice Services Specialists staff the aircraft. Until recently, ICEC also operated a Challenger jet provided under contract with Intera Technologies, Ltd. for additional sea ice surveillance. It is equipped with two MacDonald-Dettwiler IRIS SARs imaging a 100 km swath on each side of the aircraft. It is staffed completely with Intera personnel. Both aircraft have a downlink system that allows in-flight transmission of digital radar imagery. The Challenger is no longer needed in anticipation of RADARSAT for sea ice mapping.

Table 14: Source of Icebergs S of 48°N, 1994.

1994	IIP	Other Air	AES	Ships	BAPS	Total
Drifted S of 48°N	45	143	164	84	24	**460**
Sighted S of 48°N	244	524	180	357	0	**1,305**

Atlantic Airways conducts aerial reconnaissance of the fishing fleet on the Grand Banks under contract to the Canadian Department of Fisheries and Oceans using a King-Air aircraft. Atlantic Airways is also contracted directly by AES to conduct ice reconnaissance. In addition to visual observation capability, the aircraft is equipped with a Litton APS-504(v)5 search radar that provides significant coverage of ice in their area of observation. In 1992-1994, Atlantic Airways was the largest contributor of sightings to the IIP.

The IIP ICERECDET presently uses a HC-130H aircraft equipped with a pair of Motorola AN/APS-135 Side Looking Airborne Radars (SLARs) (two antennas mounted in pods on either side of the fuselage, with common signal processing) and one nose-mounted Texas Instruments AN/APS-137(V) Forward Looking Airborne Radar (FLAR). Observation windows allow visual observation of icebergs. The ICERECDET also uses a HU-25B aircraft equipped with a Motorola AN/APS-131 SLAR. The ICERECDET deploys from St. John's, Newfoundland. The use and performance of the AN/APS-135 and the AN/APS-137 radars are discussed in detail in the following sections. The AN/APS-131 SLAR is installed as part of the AIREYE system on the HU-25B. The AN/APS-131 is very similar to the AN/APS-135. However, its antenna length is half of the length of the AN/APS-135 (2.4 m v. 4.8 m) with the result that it has a lower azimuth resolution (0.8° v. 0.47°). In a side by side operational comparison, Alfultis and Osmer (1988) concluded that the AN/APS-131 SLAR was nearly as effective as the AN/APS-135 SLAR when appropriate operating parameters were used. (Growlers were not considered in the experiment.) The difficulty in using this sensor on a regular basis, however, lies with the platform on which it is installed. The HU-25B has a relatively limited range of 750 nm with a nominal endurance of three hours which is not sufficient to permit regular examination of the LAKI. Only in very special circumstances can the HU-25B be used for IIP ice reconnaissance flights. In 1994, only 7 sorties for 18 flight hours were flown. With the transfer of the aircraft from Air Station Cape Cod to Air Station Corpus Christi, the aircraft are much less likely to be used in the future. The standard cost for the HU-25B of $3,888 per hour is relatively close to the standard cost of $4,244 for the HC-130 (see Table 1 in Annex E).

3.3.3 ICERECDET Operations

Multiple, essentially daily (with allowance for aircraft maintenance and crew rest) sorties are performed during a nominal nine-day mission (every two weeks) to St. John's. Each sortie follows a preplanned flight path, the surface track of which is determined by the senior ICERECDET representative on the mission. Fight path planning is manual, with computer (PC) tool assistance. Because of generally restricted visibility, the altitude of the flight path is procedurally constrained to be above the 6000 ft. lower boundary of controlled airspace, and is normally at or near this limit. The sorties of a single mission collectively supply coverage of a swath following the boundaries of the (model predicted) Limits of All Known Ice, and extending, in searched surface area, from about 25 nm beyond this line to as far inside the line as can be covered for the combined sorties while satisfying fuel constraints.

Iceberg detections for each type of radar depends on human pattern interpretation of the CRT display associated with the system. When the display of either radar (both SLARs are controlled from a single console) indicates a potential surface object, the responsible operator makes a decision as to the validity of the detection, its categorization as iceberg, ship, or radar target, and, for objects adjudged icebergs, the size category (growler, small, medium, large, and very large) and iceberg type. The operator then manually enters this information into a log of detected objects. During this process, each operator normally talks to the other, and may, particularly in the case of initial FLAR detection, alert the other operator as to the presence and location of detections. While reporting of FLAR detections to the SLAR operator is useful, reporting of SLAR detections to the FLAR operator is of relatively less utility, since objects not detected by the FLAR operator can not be locked on to permit the Inverse Synthetic Aperture (ISAR) mode to be utilized.

FLAR lock-on requires operator placement of a cursor on the search display, which is variably illuminated by the sea clutter returns. A separate small CRT is used to present a pre lock-on range profile which is bracketed by parallel horizontal bars. The SLARs are consistently operated in the 27 nm full scale mode (1/500000 scale factor), and at the maximum PRF. Right and left side SLAR images (two film strips, 4.5 inches wide, developed in real time from CRT outputs, with dot density proportional to the log of the imaged dBms) take the form of small (.5 mm by 2 mm or more, depending on range) lozenge or lens-shaped dark regions elongated parallel to the aircraft motion, reflective of the limiting .47 degree azimuthal resolution of the SLAR. The central one-half of SLAR images on one or both sides are frequently uniformly gray to dark gray due to Bragg scattering from the sea surface. The outer half of SLAR images typically exhibits alternate bands of sea clutter and radar shadows on the sea surface. In some cases, one side of the film will be almost uniformly dark gray while the other side is almost totally unexposed due to a surface clutter viewing angle sensitivity. SLAR operators make adjustments to both antenna azimuth boresight and image saturation at their discretion.

FLAR inverse synthetic aperture (ISAR) images, when obtainable, are extremely unstable in the crossrange direction, taking the form of undulating bands (period of 4-8 seconds) of light and dark spots. Operator discrimination of a ship target was, in one case, based on the identification of a familiar (to the operator) pattern characteristic of a conning tower.

Each radar has aircraft motion compensation subsystems, and an independent navigation system. The AN/APS-137 FLAR provides a latitude/longitude and velocity readout on the auxiliary display for any cursor-selected object in track, while the AN/APS-135 SLARs provide for film display of latitude and longitude lines, from which object coordinates are estimated manually. Navigation errors are not insignificant (a nominal 5 nm is assumed for recorded positions), and may create erroneous correlations in a target-rich detection environment. Object resightings on subsequent flight path legs do not form the basis for additional operator log entries if correlation is considered adequate, but may result in reclassification or sizing of the object. Log entries are in pencil, and the latest sighting coordinates/time on a correlatable resighting is substituted as the sole log entry for the object. Subsequent to completion of the mission, the IIP senior officer reviews the logs of the radar operators, may supply additional changes or corrections, and merges the logs to create a unified list of sighting coordinates, times, and object category and size.

3.3.4 Search Patterns

Patrols are conducted using a Papa Sierra parallel search pattern with a track spacing of 25 nm. The SLAR range scale is set at 27 nm so that the SLAR coverage is nearly 200%. The purpose of the 200% coverage is to try to ensure that small icebergs and growlers are detected and to provide a means of determining target movement and aid in identification of a radar target as an iceberg. Typical search patterns are illustrated in Figure 8. Where possible, tracks are oriented in a N-S or E-W direction (or at least cardinal headings) to facilitate georegistration of the sightings which is accomplished manually.

The track spacing and SLAR characteristics result in almost one-third of the search area having a 100% coverage rather than 200% coverage and no opportunity for the SLAR operator to assess target motion and assist in identification of icebergs. There appears to be no recorded analysis of the probabilities of detection over the search area. This assessment is important for determining the risks associated with the current search procedure.

3.3.5 AN/APS-135 Probability of Iceberg Detection

Three studies pertaining to the AN/APS-135 SLAR are available: the BERGSEARCH'84 evaluation performed by CANPOLAR consultants for the Canadian government, in which several air surveillance radars were evaluated (Rossiter et al., 1985), and two other studies by IIP personnel and the CG

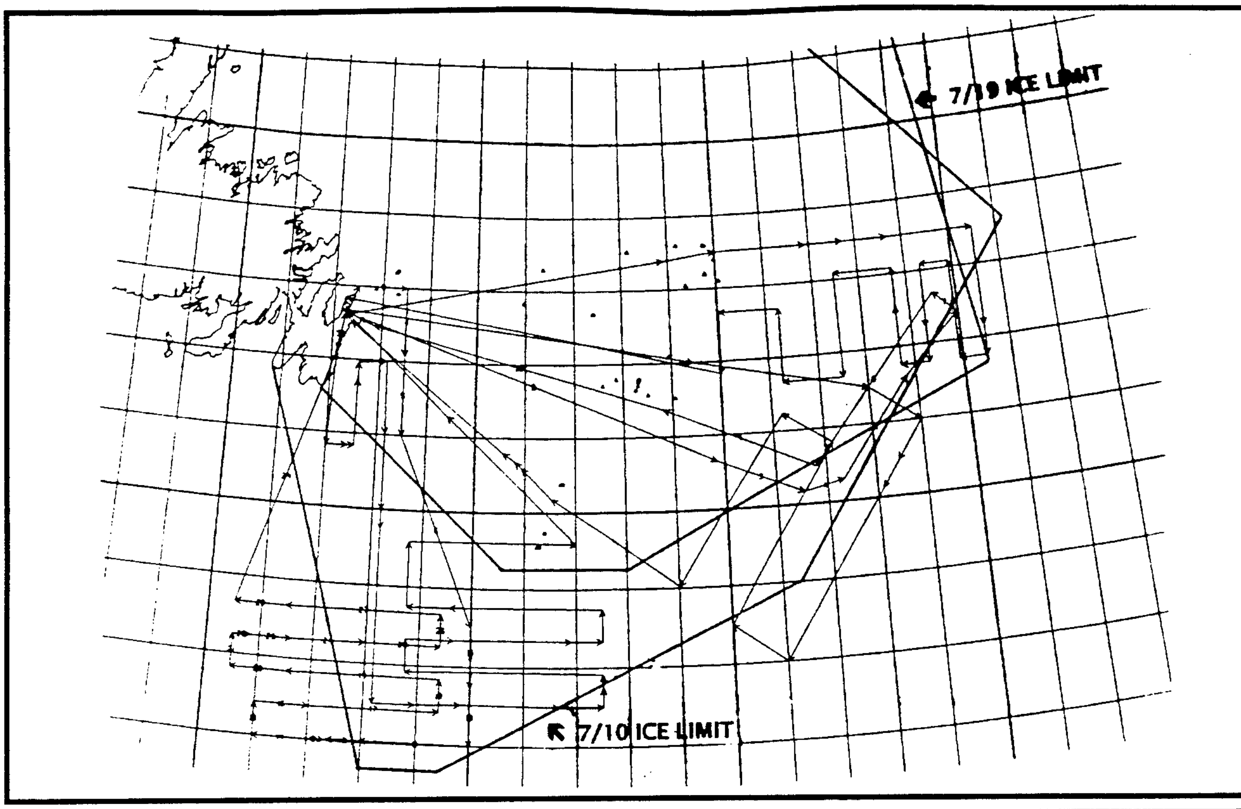

Figure 8: Ice Reconnaissance Search Patterns.

R&D Center (Robe et al., 1985; Alfutis and Osmer, 1988).

The BERGSEARCH'84 study examined five imaging radars, including the AN/APS-135 SLAR (Rossiter et al., 1985). Surface truth data was obtained from a dedicated surface vessel and aerial cameras flown at low altitude in a small commercial aircraft. A variety of wind, viewing angle, and wave height conditions were encountered over the six day period of observation. Detection results are included in Table 15.

The 1985 IIP SLAR study evaluated only the AN/APS-135 for detection capability of bergs and small boats (Robe et al., 1985). Accurate truth data was

Table 15: BERGSEARCH '84 AN/APS-135 SLAR Data (Alerted Operators/25km Range Scale Setting).

Target Type**	Sea Height (m)			Search Altitude (ft)*	
	<1.0	1.6 - 2.1	2.5 - 2.9	4000	8000
Medium Icebergs (50 to 100 Meters)	23/24 (0.96)				
Small Icebergs (20 to 50 Meters)	10/12 (0.83)	15/16 (0.94)	8/8 (1.00)	4/4 (1.00)	11/12 (0.92)
Bergy Bits (10 to 20 Meters)	10/12 (0.83)	23/32 (0.72)	24/36 (0.67)	7/8 (0.88)	16/24 (0.67)
Growlers (<10 Meters)	0/2 (0.00)	4/32 (0.13)	1/24 (0.04)	1/8 (0.13)	3/24 (0.13)

* Sea Height of 1.6 - 2.1 Meters Only
** WMO Classification

collected by object size. For the conditions of present operations, in seas up to 2 meters, for alerted operators, the Medium Iceberg (75m) target detection probability was estimated at nearly one hundred percent, while Small Iceberg (20-40m) and Growler (3 m to 15 m) detection probability was nearly 95%. The results are included in Table 16. Note that these results are based on an alerted operator analysis—specifically, an analysis of the film on a post-flight examination. The data were obtained using a search pattern with 5 km or 10 km track spacing, providing detection opportunities at various lateral ranges.

1.6-2.1 m sea height. The Robe et al. data for small icebergs were at 0.9-1.8 m sea height while the growler detections were at less than 1 m sea height. The Alfutis and Osmer data (column 2 in Table 17) were at 1-2.7 m sea height.

The experiments have shown that the AN/APS-135 SLAR seems to perform equally well in the 0-25 km and the 0-50 km range scale settings. As a first approximation to empirically estimate the probability of detection, we combine the above results in Table 19. These estimates generally represent an alerted operator situation and were computed in a post-flight laboratory setting.

Table 16: AN/APS-135 SLAR Ice Target Data (Alerted Operator).

Target Type	Search Altitude/Range Scale Setting		
	2500 ft/25 km	4000 ft/25 km	8000 ft/50 km
Medium Icebergs (75 Meters)	7/7 (1.00) Mean H_S = 0.8m	6/6 (1.00) Mean H_S = 0.7m	7/7 (1.00) Mean H_S = 0.6m
Small Icebergs (20 to 40 Meters)	41/42 (0.98) Mean H_S = 1.4m	37/37 (1.00) Mean H_S = 1.4m	34/39 (0.87) Mean H_S = 0.8m
Growlers (3 to 15 Meters)	20/21 (0.95) Mean H_S = 0.7m	46/47 (0.98) Mean H_S = 0.7m	10/11 (0.91) Mean H_S = 0.9m

A third study by Alfutis and Osmer (1988) compared the AN/APS-135 SLAR with the AN/APS-131 AIREYE SLAR in the HU-25B aircraft. All flights were evenly spaced at 4000, 6000, 8000 and 10,000 ft altitude and conducted using a 50 km range scale setting. AN/APS-135 SLAR detections/opportunities over all altitudes for the three sizes of icebergs observed are included in Table 17. The one missed detection for the small iceberg was in the 20-27 nm range.

The results from the three studies are summarized in Table 18. The BERGSEARCH '84 data represent

The results in Table 19 represent system capability parameters. Alfutis and Osmer (1988) also recorded the operator misses. The probability of operator detection of a system detected target is included in column 3 of Table 17. Because there are no observations for growlers, the probability of operator detection for growlers is estimated to be the same as that for small icebergs. It is likely that this number overestimates the probability of iceberg detection by the operator. Thus, the probability of an iceberg being detected by the system and the operator is estimated in column 2 of Table 20. Alfutis and Osmer (1988) also recorded the number of times that the operator misinterpreted an iceberg as a ship. The correct identification factor for small icebergs was 43/45 (0.96), for medium icebergs was 115/119 (0.97), and for large icebergs was

Table 17: AN/APS-135 SLAR Ice Target Data (Alfutis and Osmer, 1988).

Target Type	System Detections/ Opportunities (POD)	Operator Detections/ System Detections (POD)
Small Icebergs	47/48 (0.98)	45/47 (0.96)
Medium Icebergs	132/132 (1.00)	119/132 (0.90)
Large Icebergs	17/17 (1.00)	16/17 (0.94)

Table 18: AN/APS-135 SLAR Ice Target Data Summary.

Target Type	BERGSEARCH '84 8000 ft/25 km	Robe et al. 1985 8000 ft/50 km	Alfutis and Osmer, 1988 4000-10,000 ft/50 km
Large Icebergs			17/17 (1.00)
Medium Icebergs		7/7 (1.00)	132/132 (1.00)
Small Icebergs	11/12 (0.92)*	34/39 (0.87)	47/48 (0.98)
Growlers	19/48 (0.40) * **	10/11 (0.91)	

* Slightly Different Classification by Size
** Includes Bergy Bits and Growlers

lateral range curve. However, at the normal 6000 ft search altitude, the radar has a blind spot extending 2 nm on either side of the tack line. Hence, the lateral range curve will be as depicted in Figure 9.

Table 19: AN/APS-135 SLAR Ice Target Estimated System POD.

Target Type	Estimated System POD
Large Icebergs	**17/17 (1.00)**
Medium Icebergs	**139/139 (1.00)**
Small Icebergs	**92/99 (0.93)**
Growlers	**29/59 (0.49)**

1.00. As with growler detection, we assume that the identification probability for growlers is the same as for small icebergs. Applying these factors yields a final estimated operator probability of detection and identification of icebergs in column 3 of Table 20.

All of the experiments have consistently indicated that the AN/APS-135 SLAR detects targets uniformly across the lateral range of 27 nm when operated on the 50 km scale. Thus, it is reasonable to use a definite range law to represent the

Table 20: AN/APS-135 SLAR Ice Target Operator Adjusted POD/PODI.

Target Type	Operator POD	Operator Adjusted POD/ Operator Probability of Identification
Large Icebergs	(17/17) * (16/17) (0.94)	(17/17) * (16/17) * (16/16) (0.94)
Medium Icebergs	(139/139) * (119/132) (0.90)	(139/139) * (119/132) * (115/119) (0.87)
Small Icebergs	(92/99) * (45/47) (0.89)	(92/99) * (45/47) * (43/45) (0.85)
Growlers	(29/59) * (45/47) (0.47)	(29/59) * (45/47) * (43/45) (0.45)

3.3.6 AN/APS-137 Probability of Iceberg Detection

Two evaluations (1991 and 1993) of the AN/APS-137 FLAR system have been conducted. However, the report of the second evaluation (Trivers and Murphy, in preparation) is not yet available for review. The 1991 AN/APS-137 FLAR evaluation (Ezman et al., 1993) involved HC-130 flights over a four day period and utilized altitudes and search ranges on either side of present FLAR operating conditions . Truth data was supplied by a surface vessel (USCGC BITTERSWEET). On each of the four days, one surveillance flight covering the entire area of interest was carried out by an AN/APS-135 SLAR equipped HC-130 for reference purposes. At the 32 nm range setting at a 6000 ft search altitude, the AN/APS-137 was found successful in four of four opportunities, and over four flights on the 64 nm scale, detected 17 of 18 icebergs. Over all flight altitudes and range settings (13 flights) the FLAR operators detected 48 out of 54 (POD = 0.89) actual iceberg targets, and correctly identified 39 of 48 (adjusted POD = 0.72) as icebergs. The data included in the report does not include the lateral range of detection. (It could be estimated from the target positions given in the report.) Enclosure 1 to the report suggests that a medium iceberg is detectable at the outer limits of the 8, 16, and 32

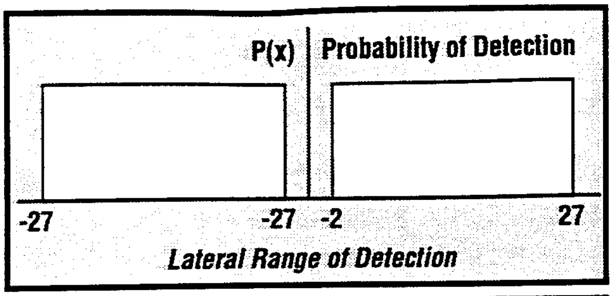

Figure 9: AN/APS-135 SLAR Estimated Lateral Range Curve.

nm range scales. The 54 detection opportunities shown on the ground truth figures included 3 small, 44 medium, and 7 large icebergs. The report does not analyze detection by target type as was done in the SLAR analyses. Enclosure 2 to the report also notes that 2/3 of the screen was obscured with sea clutter when operating in the 32 nm scale. The report recommends operating on the 64 nm scale which has been adopted by IIP.

Data in the report are difficult to interpret. A cursory examination suggests that the probability of detection may actually be lower than that indicated above. The iceberg searches in this analysis were conducted using the search mode. Parallel analyses of liferaft detection capabilities were conducted using periscope mode at lower altitudes. The 1993 analysis indicated that the best liferaft detection performance for FLAR was between 350° and 010°R and that performance dropped off significantly at relative bearings greater than ± 045°R. At ± 010°R, the lateral range on the 64 nm scale would be 11.1 nm; at ± 045°R, the lateral range on the 64 nm scale would be 42.3 nm. At this point, there is not enough information available to estimate whether the definite range law would apply, and if so, what is the appropriate lateral range at which detection will not occur?

The figures in the report depicting the FLAR patrols and sightings indicate a significantly larger number of radar targets in the area than known icebergs and ships. It is suggested that a possible source of this discrepancy is the use of INS navigation and a repeat sighting on an adjacent search leg may also be identified as a separate target. Because of the nature of the ground truth, the above POD results should only be used for medium or large icebergs.

3.4 BASELINE SUMMARY

The above descriptions of the management, technology, and operations of the IIP establish a baseline for performance and cost against which the selected alternatives can be compared. The alternatives are presented in a similar order.

4.0 EVALUATION OF SELECTED ALTERNATIVES

The several sets of alternatives are evaluated in the following sections. In some cases, the evaluation of the alternatives results in the discovery of new information that may have a potential impact on the program in the future. These findings are also included in this section.

4.1 MANAGEMENT ALTERNATIVES EVALUATION

In order to obtain meaningful input for evaluation of the management alternatives, it was necessary to seek direct inputs from the Ice Services Branch, Environment Canada (ISB) and from the National Ice Center (NIC). Because of the international and interagency dimensions of this data collection effort, requests for information were made using a structure termed an "Inquiry of Interest." It was emphasized that the inquiry and any response to it were not contractual and were made to develop information for planning purposes only. Separate requests were made to both ISB and NIC. The complete ISB Inquiry of Interest and NIC Inquiry of Interest are included as appendices to Annex F which contains a detailed evaluation of the responses by ISB and NIC.

The ISB Inquiry of Interest contained two distinct elements: a request for a proposed surveillance scheme to provide a level of performance equivalent to that currently provided by Coast Guard surveillance, and a proposed management structure to effect the day-to-day management of the entire IIP operations under the direction of a Coast Guard COTR.

The NIC Inquiry of Interest focused on the National Ice Center providing complete management of the IIP, including provision for surveillance. It recognized that NIC does not have in house surveillance resources and that arrangements for continuing Coast Guard surveillance or contracting for surveillance would be required.

Both ISB and NIC provided timely and responsive proposals to the respective Inquiry of Interest. The ISB response is included in Appendix III and the NIC response is included in Appendix IV to Annex F. The following sections summarize the proposals and evaluate the essential elements. The individual proposals merit separate reading.

4.1.1 Canadian Management of the IIP

The Ice Services Branch management proposal assumes that ISB will also be responsible for conducting surveillance. ISB proposes to use a total of nine full time equivalent personnel to manage the IIP program. Primary iceberg forecasting and analysis will be accomplished by a two person analyst/forecaster team during the ice season. One computer scientist will be assigned systems maintenance responsibilities. Computer operators will provide continuous data monitoring. An iceberg scientist will be responsible for monitoring program development. The ISB proposal assumes that CG COMSTA BOSTON/NMF will continue to provide broadcasts and that FNMOC would continue to provide environmental data. The proposed staff will assist in scheduling iceberg reconnaissance flights. Personnel requirements are summarized in Table 21.

The proposed structure will permit effective delivery of required IIP products using existing capabilities. ISB proposes to continue the same quality assurance functions and to maintain the current database. In addition, ISB notes the BAPS (DMPS) capability to automatically identify sightings outside of the LAKI (called an ALERT). ISB suggests that these could be automatically distributed to agencies responsible for safety broadcast. IIP experience suggests that some operator evaluation and review be conducted before ALERTS are released to guard against misreported positions, data entry errors, and other elements that could yield a "false positive." ISB is very clear that their management responsibility is subject to the oversight of the Coast Guard COTR. ISB proposes that IIP personnel be assigned to ISB during the transition period.

ISB will use the computer operators to provide 24 hour monitoring of data reception and dissemination, make backups, and perform other functions to ensure the reliability of the system. With full management responsibility, ISB will schedule all surveillance to take advantage of weather opportunities. ISB anticipates the use of backup surveillance resources to schedule all patrols of the LAKI in a two or three day period to take advantage of favorable environmental and oceanographic conditions.

Although not requested in the Inquiry of Interest, ISB included a well structured section on Iceberg Research and Development and included an iceberg scientist in the staffing to head this effort. This individual would have responsibility for operation and development of iceberg models, model verification schemes, implementation of new techniques, and model upgrades.

The ISB will assume all responsibility for purchasing and deployment of the WOCE drift buoys as well as maintaining the Labrador Current file. The

Table 21: Canadian IIP Management Staffing.

Staff Requirements and Responsibilities		
Section Head	1.0	Management of IIP Iceberg Mission
Forecaster	1.5	Database Management and Product Preparation
Analyst	1.5	Quality Assurance/Analyses
Computer Scientist	1.0	System Maintenance and Enhancements
Archivist	0.5	Data Management
Scientist	1.0	Program Development
Computer Operator	1.5	System/Data Monitoring and Control
Clerk	1.0	Section Administration

existing ISB infrastructure provides significant flexibility with regard to personnel and with regard to system maintenance and contingency planning.

The ISB cost proposal assumes that IIP and ISB services are integrated operationally. Appropriately, the cost proposal only shows the IIP mission share of the costs. The following costs are in $US (at an exchange rate of 1.41). The rate is a recent 18-month high. An average rate should be used for evaluation. There are three major elements: Direct labor (salary) of $277,000; Informatics and Operations costs of $299,000 (this includes $121,000 of capital depreciation, presumably for the BAPS hardware); and Corporate Support and Program Development costs of $283,000. The total management cost for the program is $859,000.

4.1.2 National Ice Center Management of the IIP

The National Ice Center submitted a proposal with two options, each dealing with a different surveillance component. This analysis is restricted to the management component. NIC has proposed that the U.S. Coast Guard maintain funding responsibility for the IIP and that the IIP operate within the management structure of the NIC. Specifically, this requires relocating IIP personnel to the NIC where IIP would become a Department. The number of personnel involved depends on the surveillance option selected.

Under Option A (contracted surveillance), a total of ten persons are required. The existing Commanding Officer and Executive Officer billets and the Aerial Ice Observer billets are eliminated. Watchstanding requirements are unchanged from current IIP procedures. Data collection and processing and information distribution continue as currently performed. NIC proposes that DMPS and DMPS2 be installed on new a HP workstation as currently planned by IIP. Existing products and distribution channels will be continued.

Under Option B (continue Coast Guard surveillance), a total of fourteen persons are required, adding one DWO and three watchstanders to the Option A allowance. These personnel will allow personnel to serve as Aerial Ice Observers on the Coast Guard HC-130 surveillance flights.

Both options under the NIC proposal continue present IIP procedures using Coast Guard personnel. The proposed personnel allowance for both options provide slight savings by reducing the CO and XO positions. Under the option involving Canadian contracted surveillance, it is not clear where the ice observers are staffed.

Under NIC Option A, the total management costs are $747,000, including $487,000 for personnel. Using the 1995 standard personnel costs, the 1995 USCG personnel costs for the proposed allowance of ten persons is summarized in Table 22. The total cost of $530,871 exceeds the estimated $487,000 used in the NIC proposal.

The management costs in the NIC proposal do not include the significant administrative (overhead) expense included in the baseline costs for IIP operations. This difference needs to be recognized when making comparisons among the alternatives. In addition, it is not clear where the routine administrative and management tasks currently performed at IIP will be performed and how they will be costed.

4.1.3 Evaluation

Both the ISB and NIC management proposals address the operation of the IIP effectively and provide structures that appear to be capable of continuing the mission consistent with the present operating procedures. The ISB proposal identifies a need for nine persons to accomplish the task while the NIC proposal requires ten persons. The ISB appears to have a stronger infrastructure for integrating the IIP mission.

Cost comparisons for the management proposals are included in Table 23. If the NIC personnel cost estimates are adjusted to reflect Coast Guard standard costs, the total cost of the NIC management proposal is $790,900. For purposes of comparison, it is assumed that Coast Guard management requires 11 personnel, those in Table 22 plus an O-5 Commanding Officer. In comparing the costs, note that there are significant differences in the

Table 22: IIP Personnel Baseline Costs, 1995 — NIC Option A.

		1995 Standard Costs					
IIP Allowance	**No.**	**Salary**	**PCS**	**O&M**	**Training**	**Medical**	**Total**
LCDR (O-4)	1	$65,346	$1,858	$3,257	$1,431	$2,917	**$74,809**
LT (O-3)	1	$59,031	$1,858	$3,257	$1,431	$2,917	**$68,494**
MSTC (E-7)	1	$40,514	$1,416	$2,999	$672	$2,917	**$48,518**
MST1 (E-6)	1	$34,609	$1,416	$2,999	$672	$2,917	**$42,613**
YN1 (E-6)	1	$34,609	$1,416	$2,999	$672	$2,917	**$42,613**
MST2 (E-5)	2	$29,249	$1,416	$2,999	$672	$2,917	**$74,506**
MST3 (E-4)	1	$24,008	$1,416	$2,999	$672	$2,917	**$32,012**
GS-14	1	$86,300	$503	$2,506	$244		**$89,553**
GS-11	1	$54,500	$503	$2,506	$244		**$57,753**
Total Personnel Cost							***$530,871***

cost elements and what is covered. For example, the Coast Guard costs include $321,000 as an administrative charge (30%). However, there is no equipment depreciation charge in the Coast Guard costs. The ISB, on the other hand has very low personnel costs, but does include $121,000 in depreciation. In addition, the support costs include $71,000 for professional services, roughly equivalent to at least another full-time position. Elimination of the 30% overhead reduces the actual Coast Guard cost to $864,000. This latter figure is the cash that the Coast Guard would save if it eliminated the program management and fired all of the people. This savings would just cover the ISB costs.

Based on this analysis, it appears that the ISB and NIC proposals would adequately manage the program at approximately the same cost. It is interesting to note the roughly equivalent personnel requirements.

4.2 TECHNOLOGY ALTERNATIVES EVALUATION

The technology alternatives involve data acquisition and processing and the drift and deterioration models used by the IIP.

4.2.1 Data Acquisition Systems Evaluation

Much of the existing IIP data acquisition is already automated. The specific alternative tasked for analysis is the need for a better acquisition of sighting data on ICERECDET flights. The sighting positions are extracted manually from the SLAR dry film that is gridded. The grids are based on inertial navigation system (INS) input. Elsewhere, it has been determined that initial positional accuracy of icebergs is a key element in providing reliable information to the mariner. Both the INS and the transfer process are significant sources of potential error. In 1995, hand held GPS systems were used on ICERECDET flights to refresh the onboard INS system at each turn leg in the search to reduce positional uncertainty of the grid lines on the SLAR dry film. However, the manual ex-

Table 23: Cost Comparison—Management Proposals.

Expense Category	Coast Guard (PAL: 11)	Ice Services Branch (PAL: 9)	National Ice Center (PAL: 10)
Personnel	$618 k	$277 k	$487 k
Informatics and Operations	$156 k	$299 k	$150 k
Support/Program Development	$402 k	$283 k	$110 k
TOTAL ($US k)	**$1,176 k**	**$859 k**	**$747 k**

traction process remains. In addition to the potential inaccuracies, this is a time consuming process. This is followed by the preparation of a digital file for input into the IIP models.

Atlantic Airways flies surveillance flights for ICEC. They have developed an Airborne Data Acquisition & Management System (ADAM) that automates the tasks associated with airborne data collection. The ADAM system is a real time data acquisition and management system that graphically displays spatially distributed objects on a Mercator projection chart. Aircraft position information and object position information obtained by digitally processing radar displays are integrated on a real time display. The ADAM system provides iceberg charts and prepares digital files in MANICE format. The ADAM system was the target candidate for this evaluation.

Commandant (G-EAE) has developed a similar system for Marine Environmental Protection activities and has a prototype system operating on a 486 portable computer. The prototype accepts navigational input, including GPS data, and object data entered by the operator. IIP became aware of this development at the October 1994 alternatives selection meeting and expressed a strong interest in supporting its further development. Because other Coast Guard operating programs have similar requirements of being able to locate georeferenced objects on a graphical projection, Commandant has authorized the development of an Airborne Tactical Workstation that will be installed on Coast Guard aircraft and be available for the IIP. It is anticipated that the system will function with either an analog or digital processor, although it is expected that all of the radars will have a digital processing functionality. Commander, IIP has developed a set of performance requirements for the Airborne Tactical Workstation, a copy of which is enclosed in Appendix I to Annex L. Included is a specification for being able to send real time messages. This is a performance requirement on the system to be able to complete the analysis and generate a message within the specified time that is ready to be sent to IIP. The 5 minute requirement may be excessive in comparison with the existing system where the message is sent after the flight has been completed. Note that the specification does not require real time transmission of a digital image file. It is assumed that GPS navigational information will be available on a continuous basis.

Meeting the IIP requirements will demand additional software development that will not be easily used in other programs. The obvious difference is the development of ice messages in MANICE format (specification 8). Another area is the sensor fusion problem (specification 6), particularly when non-radar information is to be incorporated. The sensor fusion algorithm may be able to aid in target classification (iceberg or ship) as well. The third area is modification of search patterns to "maximize the reconnaissance" (specification 2). This specification requires the development of an algorithm to operationalize "maximize the reconnaissance" for available sensors and selected target type. For example, target return is enhanced by taking advantage of the surface wind. This requires that the system obtain/accept surface wind data and that an appropriate algorithm be developed to develop an optimal search plan for specified objectives.

It appears that the Airborne Tactical Workstation is a viable solution to the ICERECDET data acquisition problem. The use of this device has a significant potential for reducing the uncertainty in the initial position of the iceberg/radar target with the consequent reduction in uncertainty in the development of the LAKI. IIP and the Program Manager should follow this development very closely and provide maximum support. The three software issues involving sensor fusion, classification, and "maximizing the reconnaissance" need continuing attention and reinforcement.

4.2.2 Data Processing Systems Evaluation

The specific alternatives involved an upgrade of the INTERGRAPH system or the switch to the ISIS system when it is developed. The complete treatment of this analysis is included in Annex L. The extensive data processing requirements for the existing IIP operation are described in section 3.2.1. Focusing on those requirements alone assumes that the system including data requirements

and models will continue without change. It is expected that there are additional demands for the future. These fall into three categories: digital iceberg position analysis, digital satellite image processing, and model expansion.

If the Coast Guard continues to conduct ICERECDET surveillance flights, the Coast Guard will be required to replace the technologically obsolescent AN/APS-135 SLAR radar. Present plans call for replacing the existing dry film imaging system in the SLAR with a digital recording capability. The resulting digital files will be available for further processing and postflight analysis. If the Coast Guard should contract the surveillance function, it is likely that a requirement would be generated to provide digital image files for analysis. The IIP should have the capability to conduct such analyses. It is not anticipated that there will be a requirement for a real time downlink from ICERECDET or contracted surveillance aircraft.

At present, the IIP does not utilize satellite imagery in achieving its mission. In 1995, the National Ice Center will provide available iceberg information from its National Technical Means Data capability. At some point, satellite imagery may be provided. ICEC currently makes extensive use of satellite imagery for its ice analysis in support of transportation in ice infested waters. In 1995, the expected launch of the Canadian SAR satellite (RADARSAT) will provide daily images that have potential for identifying some icebergs. If these developments prove feasible, the IIP should have the capability to utilize them and be able to process digital satellite images.

The existing drift and deterioration models provide the various state change factors with each update of the overall model. Much of the 90,000 lines of FORTRAN code takes care of the massive amount of bookkeeping that is required. Professor Alan Washburn is currently developing a stochastic model of iceberg positions that may be integrated with the existing models to develop a distribution of positions of icebergs and result in some confidence statement regarding the LAKI. Other approaches may involve the use of a simulation with the drift and deterioration models to better estimate the LAKI. If such model developments occur, the IIP should have the computing power and analytical base to incorporate those changes.

The existing INTERGRAPH system functions relatively well for present data processing requirements. One deficiency is the slow processing times, particularly when there are a large number of targets on plot. Another processing limitation is the inability to do any parallel processing. This becomes important when environmental and other input data is being input to the system. The PASCAL code that links the FORTRAN models to the INTERGRAH modules makes local modification of the system difficult. To date, any modifications have been completed by ICEC for use in BAPS and ported to DMPS. A major advantage of the existing system is the parallel operation with ICEC. Most of the enhancements to the existing system have been developed and funded by ICEC with no cost to IIP. Continued use of the INTERGRAPH system will preclude the use of remotely sensed images for direct analysis. The INTERGRAPH system cannot support analysis of digital radar files and processing of digital satellite imagery.

Although the system functionality is generally satisfactory, system reliability is an emerging problem. There were seven hard disk failures in 1994 that disabled the system and required IIP to use PC-based models to generate the products. This latter approach is much more labor intensive and limits the ability to complete a good resight analysis. It is becoming more difficult to find vendors who are capable and willing to provide system maintenance.

Upgrading the present system will require identifying commercial off the shelf hardware and selecting a contractor to convert the 90,000 lines of FOTRAN code to a new system. Commander, IIP has conducted a Benefit/Cost study of these alternatives, along with converting to the Canadian ISIS system as discussed below. The Benefit/Cost study is included in Appendix II to Annex L. The study recommends that the system be converted

to the ISIS system. The current review strongly supports that recommendation.

The ICEC has an ongoing project to develop an Ice Services Integrated System (ISIS) that will facilitate processing of multiple images. A conceptual overview of the project is included in Appendix B of Annex B. The proposed system will fully integrate the satellite image processing, SAR/SLAR aircraft imagery, and all environmental data on a geocoded/ georeferenced basis. ICEC will standardize on HP 9000 workstations for this system. Under the ICEC development plan, BAPS (DMPS) will be integrated into the system by the end of 1996. Implementation of such a system at IIP would provide a capability for using remotely sensed images. If images from RADARSAT would be effective in identifying icebergs, such a capability would be required. Actual use of such images would affect the personnel qualifications and training requirements and create a new analysis infrastructure.

The use of HP 9000 workstations will provide increased processing capability that will facilitate expansion of existing models and also permit more rapid processing of the data and models. A change to the ISIS system will ensure that the future requirements for IIP will be met. The complete cost analysis of this alternative along with the other two is included in Appendix II to Annex L. The direct (AFC-30) cost to convert to the ISIS system is estimated at $322,000 with an additional $12,000 for training in the second year. A draft of the DMPS II Resource Change Proposal (RCP) seeking funding support for this proposal is included in Appendix III to Annex L. The RCP doses not include any outyear funding for maintenance and periodic upgrades. Annual maintenance funding in the amount of $30,100 is included in the AFC-30 base for the existing system. An important qualitative aspect of this alternative is that it maintains complete interoperability with ICEC.

The IIP proposal to convert to the ISIS system is the best solution among any reasonable alternatives. It will provide the capability to meet all present data processing requirements and provide expansion capability to address future needs. It should be noted that if processing of satellite imagery evolves as an important task at IIP, personnel assignments and training requirements will have to be revisited.

4.2.3 Iceberg Deterioration Model Evaluation

The qualitative evaluation of the iceberg deterioration model indicated that the model appeared to be a reasonable representation of the actual deterioration process despite lacking a mechanism to account for the calving process. Many of the problems were identified with input data errors. The Phase II analysis was directed toward examining the model to determine if there was a need for improved data inputs by examining the sensitivity of the model output (melt rate) to changes in the input parameters.

The sensitivity analysis was conducted along several dimensions. The equations that comprise the deterioration model were examined along with their derivatives to determine the nature of the change in melt rate with respect to changes in the parameter values. This analytical sensitivity analysis was followed by an empirical sensitivity analysis that allowed an examination of the change in the melt rate with respect to joint changes in input parameters. Finally, a simulation analysis was conducted to evaluate the effect on the melt rate when the input parameters were characterized as random variables. The detailed sensitivity analysis is included in Annex G.

The key input parameters are wave height and period, sea surface temperature, relative speed, and waterline length. The analytical sensitivity analysis indicates that the melt rate varies as the square of the sea surface temperature and that rate increases with increasing temperature. That means that overestimating sea surface temperature will cause the model to melt the iceberg faster than it really melts. Melt rate varies as the 4/5 root of wave height and the change in the melt rate decreases with increasing wave height. Melt rate varies inversely with wave period. A shorter wave period results in faster melt. The melt rate varies linearly with relative speed. With respect to waterline length, longer icebergs melt slower (melt

rate is lower) and are in the system longer (more to melt).

The model input parameters were examined and dominant parameters were varied to present three different nominal scenarios. The factors that present the greatest contribution to uncertainty are the sea surface temperature and the wave height. Results show that at a sea surface temperature of 1°C, changes in wave height had the greatest effect on the deterioration, followed by wave period. In fact, the uncertainty in wave height propagated roughly thirty percent more uncertainty as wave period. Relative speed had an almost negligible effect. Results at a sea surface temperature of 6°C were similar. Uncertainty in wave height propagated roughly twenty percent more uncertainty. Again, changes in relative speed had an almost negligible effect. At a sea surface temperature of 15°C, results were almost identical to those at 6°C. Detailed results are included in Appendix C in Annex B.

Table 24 illustrates the impact of the joint variation in sea surface temperature and wave height on melt rate. The nominal values are indicated in boldface. When the nominal value of the sea surface temperature is 6°C, a 10% change in sea surface temperature results in 8% variation in melt rate while a 10% change in wave height results in a melt rate variation of 6.5%. The joint variation with sea surface temperature and wave height averages 16%. If the change in sea surface temperature is actually 1°C rather than 10%, the single variation is now 14% and the joint variation is 22%.

In contrast, a 10% variation in sea surface temperature (at 1°C) results in about a 4% variation in melt; a 10% variation in wave height alone (at 6ft) results in about 6.5% variation in melt. However, their joint 10% variation results in about 12% variation in melt. If the error is 1°C (actually 100%) rather than 10%, the single variable variation in melt is about 50% and the joint variation is 60%. The empirical sensitivity analysis demonstrates that the rates are clearly dependent on the nominal temperature.

Table 24: Ten Percent Parametric Variation in SST (6°C) and Wave Height (6ft).

SST (°C)	XAMP (cm)	MELT (cm/day)
5.4	164.6	6.470
6.0	164.6	7.080
6.6	164.6	7.691
5.4	182.9	6.954
6.0	**182.9**	**7.609**
6.6	182.9	8.266
5.4	201.2	7.428
6.0	201.2	8.128
6.6	201.2	8.829

Finally, sensitivity with respect to size classification reveals the greatest opportunity for propagating uncertainty. Table 25 illustrates the time to 100% melt for three levels of sea surface temperature with other parameters held constant at their nominal values. Table 25 makes it very clear, particularly at cold temperatures, that misclassifying an iceberg as smaller than it actually is will result in the iceberg existing long after it has been removed from the plot, even if waiting until 125% or even 150% of melt before removing the iceberg from the system.

The empirical analysis confirms the importance of having good estimates of sea surface temperature and wave height. The results confirm what has been known about the variation in melt with respect to changes in a single parameter. A new result from this analysis is the overall variation in melt with respect to joint variation in the parameters. The results suggest that this overall variation is superlinear (12-16% output variation for a 10% input variation). The most significant result is the impact of misclassification.

Table 25: Classification Variation and Time to 100% Melt.

Size	SST = 1°C	SST = 6°C	SST = 15°C
Small (60 m)	26-27 days	7-8 days	3-4 days
Medium (122 m)	55-56 days	15-16 days	6-7 days
Large (225 m)	103-104 days	29-30 days	12-13 days

The above parametric analysis provides the opportunity to isolate sensitivity effects with respect to particular parameters. It does not however provide an ability to examine the joint effects of multiple parameters unless specific combinations of changes are examined. Clearly, this becomes computationally prohibitive and there is no effective means of evaluating the resulting outcomes. An alternative means of examining these effects is to use a simulation model that considers the parameters to be random variables with specified probability distributions. A Monte Carlo simulation then can determine the distribution of an output variable of interest. Unfortunately, such a simulation is only descriptive and simply describes the system output for a given set of inputs. It does provide the capability to examine various inputs of interest and determine how the system outputs will change.

A simulation model was developed to examine the impact of iceberg size classification errors on system performance using the 125% and 150% melt iceberg deletion rules. It was assumed that the input variables were independent and normally distributed with the means equal to the nominal values used in the previous analysis. Each simulation run involved 28 half-days. The simulation involved 100 runs (total of 2800 half days). The 28 half days corresponds to the approximate revisit cycle of the IIP. Assume that the iceberg drift is such that it remains in the vicinity of the LAKI (60 nm) during that period. After 100 runs for a small iceberg (60 m initial waterline length), the average waterline length is -45.17 m with a standard deviation of 7.46 m. The distribution is approximately normal. With an initial waterline length of 60 m, a 150% melt deletion policy would set a waterline length of -30 m as the deletion threshold. Under this criterion, 97.9% of the small icebergs would be deleted by the model between ICERECDET patrols.

Similar simulations were conducted for medium and large icebergs. The resulting distributions of waterline length were also approximately normally distributed. For medium icebergs (initial waterline length of 122 m), the average waterline length after 28 half days was 12.31 m with a standard deviation of 7.07 m. This means that none of these will have been deleted by the model (waterline length of -61m) by the time of the next patrol, but that most of them will be very difficult to detect. If resighted, they should be classified as a small iceberg and would be deleted in the next 14 day period. The probability that a medium iceberg will remain a medium iceberg at the next 14 day sighting is less than 10^{-5}.

For large icebergs (initial waterline length of 225 m), the average waterline length after 28 half days was 118.1 m with a standard deviation of 6.38 m. As with medium icebergs, none of these will have been deleted by the model (waterline length of -122m) by the time of the next patrol. Approximately 23% will still be classified as large icebergs and the remaining 77% will be classified as medium icebergs.

The above results obviously depend on the nominal values of the input parameters. Clearly, these change over the IIP area of responsibility. In one area a nominal SST of 6°C is reasonable (virtually all observations in the 0-12°C range and two-thirds in the 4-8°C range). In other areas, different values should be used. Nonetheless, the variability represented should more than adequately capture measurement uncertainty. The above analysis suggests that the 150% deletion policy provides good protection against deleting an iceberg prematurely in those areas where the environmental parameters hold and the iceberg drift is such that it remains in the area.

This evaluation and sensitivity analysis of the IIP iceberg deterioration model has concluded that the model appears to be a very reasonable representation of the deterioration process, with the exception of calving for which meaningful data will be impossible to obtain. This conclusion is supported by our review and that of others described previously. The analytical and empirical sensitivity analyses indicated that sea surface temperature and wave height are very important parameters in the model with respect to their effect on the output (melt rate, time to melt). However, any adverse impacts that errors in these parameters may have are completely overshadowed by

the effects of misclassification of the iceberg (wrong specification of the initial waterline length). The simulation analysis indicated that uncertainty in parameter values (including sea surface temperature and wave height) are absorbed by the deletion policy, assuming that the iceberg is correctly classified. Therefore, it does not appear that further refinement of the input environmental variables is required. Any additional effort should be directed toward ensuring a correct initial classification of the icebergs.

4.2.4 Iceberg Drift Model Evaluation

The experimental evaluation of the iceberg drift model is even more limited than the deterioration model evaluations. The basic input for the drift model is the iceberg position which identifies the particular geostrophic current value, the iceberg size and shape, and the local wind history which is used to estimate the local wind driven current using another model. A detailed analysis of the models with respect to the input parameters is included in Annex H. The local wind driven current model is examined first.

The input variables for the local current model are the wind speed and direction. The analytical sensitivity analysis indicates that with respect to local wind speed, the change in the east and north components of the local current varies with the wind speed and greater increases (or overestimates of wind speed) will have a greater effect. With respect to wind direction, the effect of changes varies as the cosine of the angular error. Unfortunately, it is virtually impossible to analytically determine what the impact will be on the resulting current. The total impact of changes or data errors over all time intervals is incorporated in the sum over all time periods for both components. The first order sensitivity of current speed is easily obtained and indicates that it varies linearly with the wind speed and proportional to the cosine of the wind direction error. The first order sensitivity with respect to wind direction can also be obtained, but does not provide any immediate insight into how the current direction is affected by input data errors. Clearly, this requires an empirical sensitivity analysis to identify these effects.

Three models for local wind driven current were examined. The empirical analysis was conducted on the version extracted from the IIP computer code in SUBROUTINE NEWWIND. Nominal wind speed was 20 knots and the wind was from the south (180°). Assuming that this wind was constant over 96 hours, the resulting local wind driven current at the surface is 10.287 cm/sec (0.2 knots) at 086° using the IIP drift model. As expected from the analytical results, changes in wind direction do not have any effect on current speed. Changes in wind speed, however, do have an effect on current speed. In this case, a 10% change in wind speed has approximately a 20% change in current speed. The same results hold if the nominal wind speed is increased to 40 knots and a 10% perturbation is effected.

A percentage perturbation makes little sense with respect to direction. Instead, the effects of a ± 15° change was examined. The results are included in Table 26. The empirical results demonstrate that changes in the wind speed do not affect the current direction when the wind is constant over the period. What is interesting in this analysis is how the current direction changes. In particular changing from a wind direction of 180° to 195° results in a 165° shift in the current direction. The 15° decrease in the wind direction results in a 15° decrease in current direction. At this point, there

Table 26: Effect on Current Speed with Wind Speed and Direction Perturbations.

CURRENT DIRECTION (DEGREES)			
	Wind Direction (Degrees)		
Wind Speed (kts)	165	180	195
18	71.2	86.2	-78.8
20	71.2	86.2	-78.8
22	71.2	86.2	-78.8
% Change	-17%	—	-191%

is no obvious explanation for this counterintuitive result.

Recently, Dick (1991) prepared an Interim Report on an ongoing evaluation of the Mooney (1978) model as used for Search and Rescue (SAR) planning. She compared the SAR-Mooney model with a one-dimensional version of the mixed layer model developed by Mellor and Yamada (1982) and found that the SAR-Mooney model was inconsistent. For comparison purposes, the IIP drift model was exercised and the comparative results are in Table 27.

The results in Table 27 indicate that none of the models agree. For low wind speeds, the IIP-Mooney model is much closer to the Mellor-Yamada model, but at high wind speeds, it diverges rapidly. A very interesting result is the difference between the SAR-Mooney model and the IIP-Mooney current model. Apparently, there are two different implementations.

Dick (1991) included some preliminary recommendations (pending completion of the analysis) that the SAR-Mooney model be replaced by a more accurate model for SAR and iceberg drift purposes. If, in fact, the Mellor-Yamada model is state-of-the-art, the above comparison suggests that the IIP-Mooney model may be overestimating local wind driven current velocity. This will increase the inaccuracy of the iceberg drift, but it is impossible to identify the direction of the error.

The local wind driven current model is an important element of the iceberg drift model. The analytical and empirical analyses indicate that the current speed magnitude is somewhat sensitive to errors in the wind speed that is provided as an input. Similar analyses with respect to errors in wind direction indicate that errors in wind direction may have a significant impact on estimated current direction. Other comparisons with a SAR current model suggest that it should be replaced. The IIP current model, based on the same foundation as the SAR current model, yields significantly different results. Before any current model changes are made based on the analysis of the SAR current model, the differences between the two models must be resolved.

The main variables/parameters that affect the drift model are environmental parameters (wind speed and direction), geostrophic current, and iceberg size and shape. The interaction among these parameters determines how the estimated drift will vary.

Wind speed and direction affect the local wind driven current and also impact the model equations with respect to the above-water area of the iceberg. However, the relative impact of the water forces on the below water area is significantly larger. Therefore, based on this analysis, the environmental parameters, except for the development of the local wind driven current, have little direct impact on iceberg drift.

The iceberg classification regarding size (growler, small, medium, large) and type (tabular, pinnacled) determines the surface areas and the iceberg mass used in the model equations. To explore the impact of iceberg size selection on drift model results, we computed the ratio of the iceberg area (above the water and the four segments below the water) to the iceberg mass. This factor appears in each term in two of the model equations. Ignoring the above water area and

Table 27: Comparative Drift Model Results.

Wind Speed (m/s)	Mellor-Yamada		SAR-Mooney		IIP-Mooney	
	Current (m/s)	Direction	Current (m/s)	Direction	Current (m/s)	Direction
2.5	0.01	76	0.04	48	0.006	86
5.0	0.03	76	0.08	48	0.022	86
10.0	0.08	59	0.15	48	0.097	86
20.0	0.20	49	0.30	48	0.389	86
40.0	0.47	43	0.60	48	1.557	86

assuming that the same current was operating at each underwater level, the relative impact of the water currents is greatest for growlers and least for large icebergs. The results satisfy our intuition that other things being equal, smaller icebergs will drift faster than larger icebergs. The data seem to suggest that larger tabular icebergs will drift faster than corresponding non-tabular icebergs whereas smaller non-tabular icebergs will drift faster than smaller tabular icebergs. The present policy assumes that an iceberg is a medium, non-tabular iceberg if a positive classification can not be made. Although this appears to be a conservative policy, the "current contribution" is almost three times as great for the medium iceberg as compared with the large (non-tabular) iceberg. None of the experiments to date have attempted to identify possible effects of misclassification.

Finally, the last input that impacts the solution of the model equations is the geostrophic current. Because the geostrophic current is an average of past observations, it is inherently accurate as to its intended representation. The degree to which it corresponds to actual current is unknown in real time except for those cases where drift buoys are available. In fact, the drift buoys are used to provide a replacement for the geostrophic currents when real time drift buoy current data is available. Accuracy in geostrophic data used in the drift model is very dependent on positional accuracy.

To examine the impact of positional accuracy, we would like to estimate the probability that an iceberg is actually located in the area for which a geostrophic current is selected. The geostrophic current file is developed on a 20 second grid. Assume that the geostrophic current in adjacent north/south grids is approximately the same, but that east/west grids may have significant differences, particularly with regard to current speed. The IIP assumes that the initial error in sighting an iceberg is 10 nm on the first day, increasing by 5 nm per day up to a maximum error of 30 nm. This error distribution is normally represented as a bivariate normal distribution and the "maximum" error corresponds to 3σ. The range from -3σ to $+3\sigma$ covers 99.7% of possible locations. Under these conditions, we can assume that the marginal density of location across lines of longitude is normally distributed, and with the maximum error of 30 nm, $\sigma = 10$ nm.

Table 28 provides some insight into the potential benefits of improving the position estimation of the icebergs. In particular, if the initial position is much more accurate, for example, within 3 nm, the probability that one will select the correct geostrophic current increases to 0.97. With the correct current, there is a much higher probability that the position at the next update will be correct and that the correct values of the geostrophic current will be used in the model equations.

Table 28: Probability of Selecting Correct Geostrophic Current Using Position Error Estimates.

Day	Error	Probability
1	10 nm	.87
2	15 nm	.80
3	20 nm	.74
4	25 nm	.67
5	35 nm	.61

The result of this sensitivity analysis suggests that the local wind driven current portion of the deterioration model should be re-examined. The analyses indicate that the current speed magnitude is somewhat sensitive to errors in the wind speed that is provided as an input. Similar analyses with respect to errors in wind direction indicate that errors in wind direction may have a significant impact on estimated current direction. A comparison with a SAR current model yielded significantly different results. Before any current model changes are made based on the analysis of the SAR current model, the differences between the two models must be resolved. Other aspects of the drift model appear to provide a reasonable representation of the actual drift process. The analytical evaluation of the iceberg drift model reveals that there is little need for improved estimates of the environmental parameters for direct use in the drift model. The analysis illustrated the importance of correct classification. It is suggested

that the present policy of classifying unknown icebergs as non-tabular medium icebergs be reexamined. Finally, the sensitivity of positional accuracy was clearly illustrated for the drift model. It is important to be able to improve the initial positioning accuracy to ensure that the probability of using the correct geostrophic current is maximized.

4.2.5 System Risk Modeling Approach

The selected Phase II alternative was to conduct the sensitivity analysis of the drift and deterioration models and to develop an approach to characterize the risk posture for the IIP. A detailed discussion of risk and development of a modeling approach to characterize risk is included in Annex K.

Risk involves both the notion of uncertainty and the notion of damage. Risk analysis involves the quantification of risk and determining risk acceptability. In this analysis, we focus on the approaches for quantifying risk but do not address risk acceptability. Quantification of risk involves quantification of uncertainty and identifying the potential damage that can occur. Kaplan and Garrick (1981) pose three questions that assist in risk quantification: (1) What can happen? (i.e., what can go wrong?), (2) How likely is it that it will happen?, and (3) If it does happen, what are the consequences? Questions 1 and 2 characterize uncertainty, and questions 1 and 3 characterize the damage.

In meeting its mission objective, the IIP publishes information that describes the Limits of All Known Ice (LAKI). The information should be accurate and be timely. However, this information is simply a statement of what the IIP knows. It is not a statement of actual iceberg conditions. Ideally, it should be a 100% confidence statement about Coast Guard/IIP knowledge. It also is a confidence statement about the location of icebergs, but the confidence level is unknown. In practice, despite repeated cautions about the possibility of encountering an iceberg outside of the LAKI, the mariner will typically erroneously assume that the published LAKI is a 100% confidence statement about the location of icebergs.

From the Coast Guard/IIP perspective, an adverse event that may lead to damage (in a risk sense) is the actual location of an iceberg outside of the LAKI and its sighting by a vessel, or worse yet, being involved in a collision with a vessel. The potential adverse effects associated with these events include loss of Coast Guard/IIP credibility, physical damage to vessels, injury and/or loss of life, environmental damage, lawsuit for damages, and increased shipping costs due to the necessity to give the LAKI a "wider berth." The "external encounter" with an iceberg outside of the LAKI answers question 1 and the various adverse effects characterize the damage and answer question 3. In order to make progress in the risk analysis, it is necessary to answer questions 2: how likely is an external encounter? This leads to an uncertainty analysis, which for the IIP operations, is the heart of the risk analysis.

Uncertainty analysis examines the total uncertainty induced in the output of the model by quantifying the uncertainties in the inputs to the model and the quantities within the model itself. It also considers the relative importance of all sources of uncertainty in terms of their contribution to the total uncertainty. The uncertainty in the output involves whether the LAKI in fact contains all icebergs. Ideally, the probability that an iceberg is encountered outside of the LAKI is equal to zero. Absent perfect information, we desire that probability to be as low as possible. Therefore, a reasonable objective for the IIP operations is to minimize the probability that an iceberg will be encountered outside of the LAKI. An obvious solution is to permanently inscribe the LAKI at the equator. However, there is a clear tradeoff between the location of the LAKI and the additional cost to shipping even though this tradeoff is not made explicit in any way.

There are two general ways in which an external encounter can occur: a failure to detect and classify an iceberg (while inside the LAKI and then drifts outside of the LAKI), or a modeling error that may involve any of the sources of uncertainty defined above.

To get a better feel for the various factors and their influence on determining the final outcome, these concepts are represented in an influence diagram in Figure 6. This provides additional information on how the various model inputs influence other components in the model and provide a means for propagating uncertainty to the final output, namely, the LAKI. In the influence diagram, the ovals represent activities that have a probabilistic element and the rectangles with rounded corners represent policies and decision actions that may introduce uncertainty. It is important to realize that an influence diagram is not a flow chart. With an influence diagram, it is assumed that knowledge is passed to all other elements that require the knowledge (often shown by a dashed line, but omitted here to simplify the diagram).

The major elements in the IIP operations model include iceberg detection/ classification, iceberg drift, iceberg melt, and resight analysis procedures. The results of these submodels are synthesized to determine the LAKI. In order to identify the sources of uncertainty, it is necessary to develop more refined submodels.

The essential starting point for the IIP operations is the detection and classification of icebergs. A simple influence diagram illustrating the important elements of detection and classification is represented in Figure 10. Further refinement is possible. For example, in addition to weather (visibility) and sea state (radar reflectivity), Coast Guard Detection and Classification is also influenced by skill of the on board operators, iceberg density, state of repair/ adjustment of the radars and other factors as well such as the sampling error inherent in the process due to the inability to exhaustively search the entire area. For purposes of quantifying uncertainty, it is easier to deal with the model at this level. Experimental results using radar and visual observation with ground truth observations have permitted estimation of the probability of detection and classification of icebergs using Coast Guard resources (see Annex C). Because these results were based on radar observations, weather did not affect (influence) the Probability of Detection and Identification (PODI) estimation. However, the PODI is dependent on sea state and the results are limited by the observed sea states. Therefore, obtaining meaningful probability distributions and being able to explicitly determine the dependencies and interrelationships will be very difficult.

A drift model influence diagram is included in Figure 11. Clearly the key starting point is the previous estimated position of the iceberg. Any uncertainty in this position will be propagated through the drift model.

In order to quantify the uncertainty, it is important to be able to identify the types of uncertainty that may be present for each source of uncertainty. Figure 12 suggests particular types of uncertainty for the various sources in the iceberg drift model. A sensitivity analysis of certain parameters is conducted in Annex H.

The influence diagram for the iceberg deterioration model is included in Figure 13. The deterioration model is straightforward in determining the reduction in waterline length and the new melt state. However, certain errors and uncertainties are not easily carried through the model analytically. For example, misclassification errors due to incorrect size classifications can only be examined by a sensitivity analysis. Similarly, uncertainty in positions results in selecting the incorrect sea state

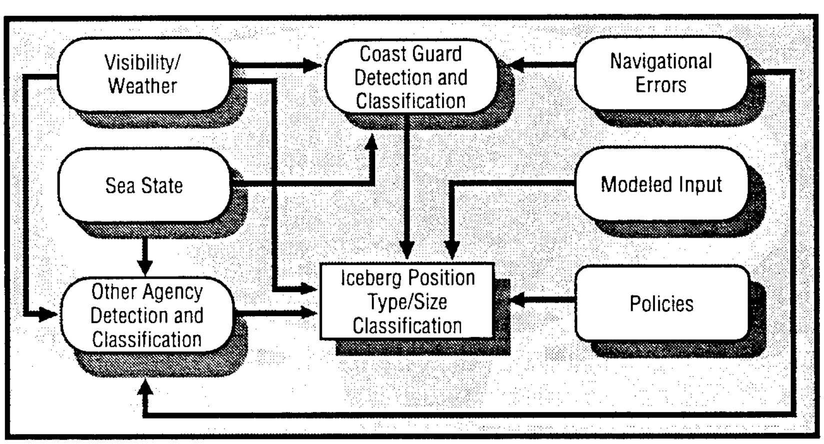

Figure 10: Detection/Classification Influence Diagram.

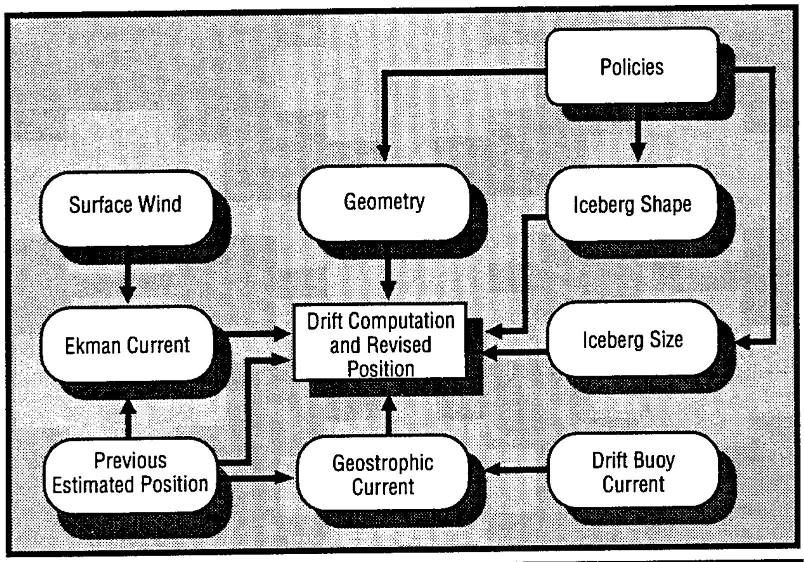

Figure 11: IIP Drift Model Influence Diagram.

and sea surface temperature, even if those data were 100% accurate.

The concept of "policies" appears in all of the above influence diagrams. These incorporate the various assumptions that are made, some of which were referred to in the description of the sources of uncertainty. These include elements such as the number of categories of icebergs, the underwater profile of icebergs, approximations used in constructing the analytic models, classification criteria for radar targets, assumed iceberg size for unclassified icebergs, estimated positional error circle and positional error growth, and similar factors. Also included as policies are factors such as resighting procedures, size reclassification on resighting, and construction criteria for the LAKI. Most of these can not be represented as probability distributions and require another approach to estimate and then propagate the uncertainty induced by their values.

	Statistical Variation	Systematic Error/Bias	Subjective Judgment	Linguistic Imprecision	Variability Due To Sample	Lack Of Scientific Knowledge	Approximations
Local Wind Velocity	✔	✔					✔
Local Wind Direction	✔	✔					✔
Position (Observed)	✔	✔	✔				✔
Position (Drifted)	✔	✔	✔				✔
Geostrophic Current	✔	✔	✔			✔	✔
Iceberg Size	✔	✔	✔	✔			✔
Iceberg Shape	✔	✔	✔				✔
Geometry							
Surface Area	✔	✔	✔		✔	✔	✔
Underwater Areas	✔	✔	✔		✔	✔	✔
Ekman Current	✔	✔				✔	✔

Figure 12: IIP Drift Model Sources of Uncertainty.

The preceding development describes a comprehensive approach for characterizing the elements contributing to uncertainty in this very complex operational system. Recall that an objective of this analysis is to be able to estimate the probability that there will be no icebergs outside of the LAKI. It should be clear than an overall analytical model is not feasible for this system. Analytical relationships simply do not exist in many cases to link the various parts of the model. Lacking the capability to construct an analytical model, the only feasible approach is to develop a simulation model to represent the system. As noted above, a simulation model is descriptive and does not optimize parameter settings. However, careful selection of parameter settings can be used to evaluate those which are most promising. In conducting the analysis of the iceberg deterioration model (see Annex G), we used a sensitivity analysis approach to examine the model output sensitivity to errors in the input parameters. However, it was necessary to use a Monte Carlo simulation using probability distributions for the parameters to evaluate the effects of iceberg size on deletion policies.

At this point, it is clear that a simulation approach is the correct way to proceed. It is expected that the existing "What-If" model at IIP would be the appropriate vehicle for conducting the simulation. The What-If model would require modification to accommodate random variates in the simulation. A significant challenge is in the design of the experiment, given the potentially large number of

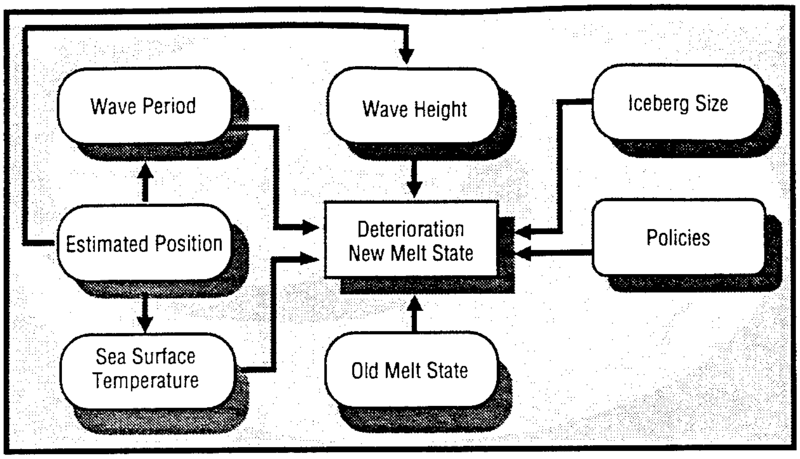

Figure 13: IIP Deterioration Model Influence Diagram.

factors. Creative use of robust design procedures would be an essential part of this effort.

Developing the above structure and examining the various submodels may lead to insights that will reduce output uncertainty without significant computational requirements. In this analysis, minimizing the probability that an iceberg occurs outside of the LAKI was established as the objective. Having that objective, a simple graphical analysis leads to a potential policy that states that one should not use limit setting icebergs as corner points in constructing the LAKI (see Annex K).

Risk requires a measure of damage and a measure of uncertainty. Damage is typically associated with the occurrence of the uncertain events. For the IIP, the undesirable event is encountering an iceberg outside of the limits of all known ice. Damage can range from a loss of credibility for the IIP to severe physical and environmental damage as well as loss of life if a vessel strikes an iceberg. A risk analysis depends on an uncertainty analysis which propagates the uncertainty in input elements (iceberg detection/classification, environmental factors, drift and deterioration models, resighting procedures, and numerous policies) to characterize the uncertainty in the output (the location of the LAKI). This analysis developed a comprehensive modeling approach for conducting such a risk analysis. Based on the sensitivity analyses of the drift and deterioration models, it is clear that an analytical representation for output uncertainty as a function of input uncertainty is not feasible. Instead, a promising approach is the use of Monte Carlo simulation utilizing the "What-If" DMPS model at IIP as a foundation.

4.3 OPERATIONS ALTERNATIVES EVALUATION

The operations alternatives involve surveillance options grouped as satellite and non-airborne surveillance, improved Coast Guard surveillance, Canadian contracted surveillance, and National Ice Center managed surveillance. Both the Canadian contracted surveillance and the National Ice Center managed surveillance address commercially contracted surveillance.

4.3.1 Satellite and Non-airborne Surveillance

The Phase II requirement was to take a brief look at RADARSAT and Ground Wave Radar. This section examines recent developments and opportunities with both systems. These are discussed further in Annex I along with a review of potential small commercial satellite systems. The Ground Wave Radar and a satellite image processing system that could be used with RADARSAT are involved in a newly planned experiment (BERGSEARCH '95) scheduled for Spring, 1995. The purpose of the experiment is to provide another evaluation of the Ground Wave Radar capability and to evaluate the potential of the SAIC IPAP image analysis system for use with RADARSAT images.

The previous evaluation of Ground Wave Radar by Canada in 1992 was very negative. The prototype High Frequency Ground Wave Radar system at Cape Race, Newfoundland built by Northern Radar Systems Limited has a claimed nominal detection range of 125 nm for large icebergs. They have planned a major upgrade to provide 150 nm detection of small icebergs and 250 nm detection of large icebergs. The system is also supposed to provide for measurement of surface currents, waves and sea state, and surface wind. ICEC evaluated the GWR performance comparing their

reports with the results of IIP flights in the same area on May 30 - June 1, 1992 (Power, undated). The conclusion of the study is that there was little correlation between the Cape Race GWR reports and the IIP observations. The purpose of the evaluation in BERGSEARCH '95 is to evaluate the effectiveness of the improved system.

Section 7.3 of Annex B summarizes satellite technology options for the IIP. ICEC currently uses ERS-1 and NOAA AVHRR images in its sea ice program. The AVHRR images are infrared and hence dependent on visibility. The AVHRR swath width is 2700 KM with a resolution of 1.1 x 1.1 km. Clearly, even without clouds, AVHRR would not provide a reliable means of detecting icebergs. The ERS-1 C-band (VV polarization) SAR resolution is much better, approximately 30 m, but it has a smaller swath width of 80 km.

The most promising alternative is RADARSAT, now scheduled for launch in mid-late 1995, that will be operated by the Canadian Space Agency. RADARSAT is intended to provide all weather coverage of the Canadian ice covered waters to facilitate ice forecasting for shipping. RADARSAT has eight imaging modes. ICEC intends to primarily use the ScanSAR(Wide) mode with a swath width of 500 km and resolution of 100m. The finest resolution of 12x9 m is provided by the Fine Res mode with a 45 km swath width. The various modes are illustrated in Figure 14.

In the ScanSAR(W) mode, RADARSAT will have a difficult time meeting the spatial sampling requirements. In the FinRes mode, it will be difficult to meet temporal sampling requirements and provide the coverage needed with a 45 km swath. The ICEC has concluded that the ScanSAR(W) mode will not be able to detect icebergs on a regular basis. It is possible that RADARSAT may provide early imaging of large icebergs upstream. To date, no one has explored the possibility of using a finer resolution mode.

Recently, SAIC has developed a computer-based image analysis system named IPAP (ERS-1 Pilot Application Project for Polar Operations) that is designed to take ERS-1 SAR images and produce a range of data products to serve the needs of the polar community (Hodson and Partington, 1994). One of the identified needs is detection and identification of icebergs requiring 5m resolution. SAIC has prepared an image analysis using ERS-1 data (with nominal pixel resolution of 100m) that yields a POD of 1 for large icebergs, 0.89 for medium icebergs, and 0.44 for small icebergs (Hodson and Partington, 1994). The probabilities were com-

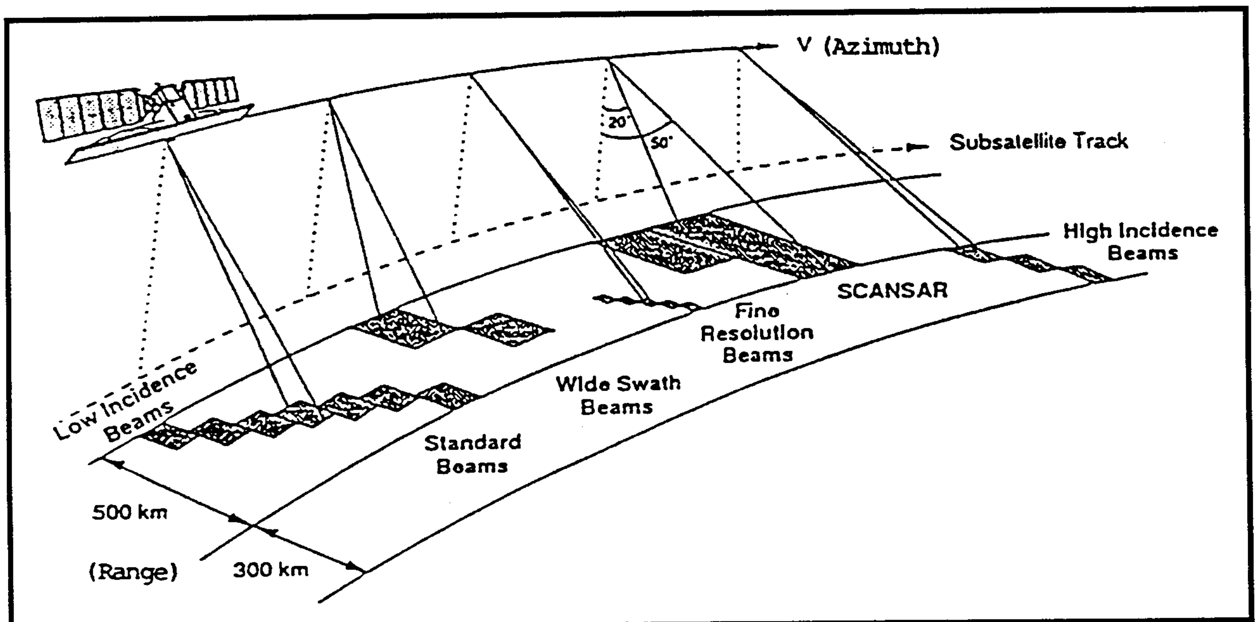

Figure 14: RADARSAT Modes of Operation.

puted by comparing the IPAP detections with IIP reports of iceberg positions. The numbers of icebergs considered is not included in the report. Moreover, the image presented includes many more detections than icebergs. Whether these are ships, false alarms, or undetected icebergs is an open question and part of the reasons for further evaluation. The intent of BERGSEARCH '95 is to execute the experiment when ERS-1 is favorably located with respect to the experimental area. IIP will provide ground truth through an ICERECDET sortie.

If the experiment is successful and IPAP is able to generate reasonable images of iceberg locations using ERS-1 data, at least for large icebergs, there is a reasonable chance that such a system may be productive with RADARSAT images. A partnership agreement with Canada to process their RADARSAT images and provide the analysis results may provide a means to reduce surveillance requirements. If such a capability develops, it is important to identify the required frequency of the product. At present, the Coast Guard has indicated a need for weekly RADARSAT images. This approach would retain a strong reliance on the models. A more frequent update would put more emphasis on near real time information and reduce the dependence on the models.

4.3.2 Improved Coast Guard Surveillance

The specific alternative to be addressed involved the improved use of SLAR/FLAR and the possibility of improving coverage using a SAR radar system (e.g., STAR-2). A major motivation for this alternative is the impending "technological obsolescence" of the AN/APS-135 SLAR radar. In addressing this task, the current use of SLAR/FLAR is reviewed and performance levels are evaluated. The implications of performing the mission with FLAR alone are considered and evaluated. Finally, an enhanced SLAR is reviewed as an alternative to the acquisition of a SAR system. A more detailed analysis is included in Annex J.

The primary source of sighting information in the vicinity of the LAKI is Coast Guard surveillance patrols. On the average, the ICERECDET deploys to St. John's, Newfoundland approximately 15 times per year. Most of the deployments use HC-130 aircraft from Air Station Elizabeth City, NC, incurring a significant enroute cost for the deployment. In addition, there are periodic requirements for logistics/maintenance flights. The total flight hour breakdown for 1991-1994 is shown in Table 29. Patrol hours constitute about 70% of the total flight hour requirement.

Table 29: IIP Aircraft Flight Hours.

Year	Transit	Patrol	Research	Logistics	Total
1994	140.7	404.4	0.0	31.5	**576.6**
1993	160.5	435.3	16.0	55.2	**667.0**
1992	182.6	348.2	0.0	92.8	**623.6**
1991	155.3	282.1	59.1	79.8	**576.3**

The present use of the AN/APS-135 SLAR and the AN/APS-137 FLAR radars is discussed in detail in sections 3.3.3-3.3.6 of this report. In that analysis, the resulting probabilities were developed for the two radars separately. In fact, the lack of data on the FLAR performance effectively precludes further quantitative analysis. The Trivers and Murphy (in preparation) report should provide additional information to assist in further analysis. Despite the lack of quantitative measures, there are important qualitative measures that can be used to assist in deployment of these radars. Present practice uses the FLAR to enhance the identification capability of the SLAR.

Given that the SLAR or FLAR system presents a radar target, it is important to the IIP to know whether the target is an iceberg or a ship. The SLAR operators have developed considerable expertise in recognizing icebergs. The correct identification factors in the Alfutis and Osmer (1988) study ranged from 0.96 to 1.00. These factors were applied to obtain the operator adjusted POD in Table 20. Note that these values are probably upper bounds in that the various searches were conducted at 5 nm and 10 nm track spacing, giving the operators ample opportunity to acquire the target on subsequent passes and determine whether there is any movement in the target location. This is the principal mechanism for identify-

ing the target as an iceberg. The Ezman et al. (1991) results for the FLAR operators yielded a correct identification factor of 0.81. It is recognized that the operators had no previous experience with using the FLAR to detect icebergs. Subsequent experience with the FLAR suggests that it is an excellent discriminator between ships and other radar targets (e.g., icebergs). Trivers and Murphy (1994) reported that the number of unidentified targets per flight was reduced from 3.6 in 1992 to 1.8 in 1993 after introduction of the FLAR.

The identification processes using the SLAR and the FLAR are significantly different. For the SLAR, identification is made by determining that the target has relatively little movement (misidentifications of fishing vessels as icebergs are possible). During this process, except for operator attention, the detection process continues and images are presented on the dry film. With the FLAR, however, identification is accomplished in the imaging mode which requires a lock-on to the target. When this occurs, no detection is taking place. At a patrol speed of 250 kt, each minute spent imaging results in 4.2 nm of track not being searched. Using the FLAR as a sole detection device would severely limit its opportunity for imaging and identification of the targets.

The development of lateral range curves for detection presume continuous looking. The use of FLAR alone with interruptions for imaging results in an intermittent looking search pattern that results in a different (lower) probability of detection. The amount of allowable imaging is inversely proportional to the target density in order to achieve some minimum level of POD. At present, no such model has been developed for IIP FLAR operations. Search planning uses 200% SLAR coverage to achieve an acceptable probability of detection, identification and classification. If the POD from the FLAR search were known, SLAR coverage could be reduced while maintaining the same overall POD by using sensor fusion models and while maintaining acceptable classification levels. Note that such a model development is required to effectively evaluate search effectiveness using the Airborne Tactical Workstation recommended in section 4.2.1 above.

Present operation of the SLAR utilizes 200% coverage of a significant portion of the search region to minimize the probability of missing any icebergs in the area in the vicinity of the LAKI and to provide a mechanism for identifying targets as icebergs based on estimated movement. Annex C contains the development of a simple model to estimate search effectiveness for ICERECDET patrols.

Using the SLAR operator adjusted probabilities of detection and identification in Table 20 and the similar data for the FLAR, application of the model results in the search effectiveness shown in Table 30, assuming that the POD on each patrol is the same.

Table 30: Search Effectiveness for SLAR Searches.

Target Type	Probability of Detection After ith Search			
	1st Search	2nd Search	3rd Search	4th Search
Large Icebergs	0.94	0.9964	0.999784	0.999987
Medium Icebergs	0.87	0.9831	0.997803	0.9997144
Small Icebergs	0.85	0.9775	0.996625	0.9994938
Growlers	0.45	0.6975	0.833625	0.9084938
FLAR	0.72	0.9216	0.978048	0.9938534

ICERECDET patrols are typically conducted to cover a 90 nm wide swath along the entire LAKI. This usually requires four flight days to accomplish. When weather and the length of the LAKI permit, a fifth flight day is used to provide additional surveillance of the interior of the LAKI. With a 25 nm track spacing and the SLAR set on the 27 nm range scale (the lateral range curve in Figure 9 applies), the average search effectiveness is computed by weighting the POD in each section searched by the proportion of the area covered.

Applying these probabilities for a four leg and a six leg parallel sweep search pattern yields the search effectiveness shown in Table 30 for each type of target. Also included in Table 31 is the

comparable result for FLAR (search only) for medium icebergs.

Table 31: Search Area Effectiveness for SLAR Searches.

Target Type	4 Leg Search	6 Leg Search
Large Icebergs	0.97	0.98
Medium Icebergs	0.93	0.95
Small Icebergs	0.92	0.94
Growlers	0.59	0.62
FLAR	0.83	0.86

The "technological obsolescence" of the AN/APS-135 SLAR refers to the existing dry film processor technology. The dry film processor heads are no longer in production and spare parts are difficult to obtain. A limited number of boxes of film exist in the world and the cost to manufacture more film is prohibitive. It is expected that the SLAR will be maintainable through the 1996 ice season.

The previous IIP analyses have concluded that the AN/APS-137 FLAR is not a suitable replacement for the SLAR. The various analyses conducted in this report support that conclusion. Failure of the SLAR would force reliance on the FLAR and increased visual observation. Because of the reduced track spacing and the need for visual observation, IIP has estimated that an additional 2.3 sorties (14 flight hours) would be required for each ICERECDET. With an average of 15 ICERECDETs per season, this translates to an additional 210 flight hours. Using the standard cost of $4,244 per flight hour (Annex E, Table 1), the *additional annual operating cost would be over $890,000.* Given the state of knowledge of FLAR performance, it is not possible to demonstrate that this will achieve the same level of performance. At the current operating cost, it is clear that the FLAR only option will result in a degraded performance, the amount of which is unknown pending development of better FLAR data.

Another possibility is replacing the SLAR with another radar. Various SAR systems were considered and alternative sensor systems were evaluated (see Annexes J and M), but the availability of a digital SLAR upgrade at a relatively modest cost as described below precluded a need to examine further alternatives.

AC&I Resource Change Proposal (RCP No. 610) for FY 1996 provides for a "C-130 Side Looking Airborne Radar (SLAR) Upgrade" and seeks funding in the amount of $2.1 million to replace the existing dry film processor with a digital processor. Specifically, the SLAR upgrade will replace the radar signal processor, image processor, radar data recorder, radar set control, and CRT display. The upgrade provides imagery and data down link capability for real time imagery transmission to operational commanders. The SLAR upgrade is identical to the ongoing upgrade of the AN-APS-131 SLAR installed on the HU-25 aircraft. RCP No. 610 installs the upgrade on two HC-130 aircraft and provides for ground stations capable of real time receiving, transmitting, and replaying all SLAR imagery. The technology uses open system architecture for hardware and software design. Although the RCP provides for hardware, it does not appear to include development of performance parameters for the upgraded radar, specifically the probability of detection for icebergs.

The upgrade is expected to carry the sensor through 2010. The original system was acquired in 1977. With an expected life of fourteen years for the upgraded system, amortized acquisition costs amount to $150,000 per year, or the equivalent of about 35 flight hours at present standard rates. The upgraded system provides opportunities for significant cost reductions that will more than cover the acquisition costs.

The present flight procedure uses a 25 nm track spacing with the SLAR operating on the 27 nm range. The primary purpose for this setting is to prevent the film images from becoming too degraded at the next larger scale setting and adversely affect their interpretation. The radar itself has an effective range of 80 nm. With digital recording, all images are accessible for analysis. At extended ranges, it will be necessary to develop appropriate lateral range curves in order to estimate probabilities of detection. With installed GPS, a 200% coverage will eliminate any ambigu-

ities due to drift and track error using the INS and dry film and will permit reliable identification of stationary targets which can then be imaged by the FLAR for classification purposes. Suppose a doubling of track spacing to 54 nm with a continued 200% coverage was able to meet present performance requirements. (This seems to be a reasonable expectation.) Further, assume that one-third of the patrol hours are enroute hours and two-thirds were active search hours (approximately 270 hours in 1994). Doubling the track spacing will potentially reduce the search time by half, saving 135 flight hours (equivalent to $573,000 at the standard rate). Using the CGFINCEN 1994 IIP aircraft costs (see Table 4) of $3450 per hour, the savings amount to $465,000, more than a three fold positive B/C ratio.

There are a number of actions to be taken that will improve the Coast Guard surveillance. It is necessary to obtain a better estimate of performance from the FLAR radar. Models need to be developed to evaluate the search/image mode and determine the impact on POD due to intermittent looking. With that knowledge, integration with the existing or upgraded SLAR is possible with the expectation that search levels may be reduced. The acquisition of the SLAR upgrade is critical in order to maintain the existing high level of program performance. With an expected life of 14 years, the payback period is less than 4.5 years.

4.3.3 Canadian Contracted Surveillance

The Ice Services Branch (ISB), Environment Canada delivered a comprehensive proposal that demonstrated an excellent knowledge of IIP operations and mission requirements. Their surveillance is based on using the DeHavilland Dash 7 aircraft outfitted with both SLAR and FLAR radars combined with visual reconnaissance employing a "locate and identify" surveillance strategy. The aircraft will be based in Newfoundland providing reduced cost due to the elimination of unnecessary transit times and affording the opportunity to take advantage of favorable weather conditions. The ISB has provided for backup aircraft through the Department of Fisheries and Oceans and the Department of National Defence. The proposal provides for deployment of the AXBT probes by the Dash 7 and deployment of the WOCE buoys by arrangement with the Department of Fisheries and Oceans. Using 1992 surveillance requirements as a base year, the total estimated cost for providing surveillance services is $1,865,000 (1995 $US). The complete proposal is included in Annex F (Appendix III).

The essential performance requirements in the Inquiry of Interest (Annex F, Appendix I) specified minimum probabilities of detection, coverage requirements, surveillance frequency, unidentified detections, and iceberg classification. Specifically, the surveillance performance requirements for the response to this inquiry are summarized as follows.

- Provide surveillance with the following probability of detection and identification.

Iceberg Type	**PODI**
Large iceberg (126-213 m)	0.98
Medium iceberg (61-125 m)	0.96
Small iceberg (15-60 m)	0.95
Growlers (< 15 m)	0.85

- Provide surveillance coverage over a 125 nm swath of the Limits of All Known Ice.
- Provide surveillance at least bi-weekly.
- Provide surveillance so that the average percentage of unidentified radar targets within 60 nm inside of the LAKI is less than 10% and zero outside of the LAKI.
- Provide the capability to deploy AXBTs and WOCE buoys.

To meet the POD requirements, ISB proposes to use a "locate and identify" search mode with the CAL-200 SLAR and a new (unspecified) FLAR radars. The proposal asserts that this approach is "more efficient" than the 200% SLAR coverage employed by the U.S. Coast Guard. This conclusion is apparently based on the experienced judgement of the Canadian ice observers. The proposal does not provide any supporting material to justify the approach or attempt to quantify

Table 32: Adjusted ISB Surveillance Costs, 1992 Surveillance Levels (1995 $US).

Target Type	Reported ($US)	Adjusted ($US)
Ice Observer Labor	187	187
Aircraft Costs		
Basing Charge (52.9/mo)	225	300
Flying Charge (845/hr)	252	252
Maintenance	103	103
Hangarage	14	19
Contingencies	71	71
Equipment Costs	92	92
Direct Operating Costs	115	115
Indirect Costs	71	71
Capital Costs	735	735
TOTAL	**1,865**	**1,945**

the POD for various sizes of icebergs. Based on the information in the proposal, it is not possible to determine if the proposed approach meets the present level of performance for detecting icebergs.

The effective endurance of the Dash 7 is 1400 nm. (For planning purposes, the USCG uses 1700 nm for the HC-130.) ISB has examined the ability of the Dash 7 to provide coverage of the LAKI (15 June 1992 was the extreme limits during the 1992 ice season extending to 039.5°W) and has provided reasonable justification for the Dash 7 using the locate and identify search strategy. If another search strategy is used, coverage will have to be verified.

ISB estimates that an average of five sorties requiring a total of 35 flight hours will be required to cover the LAKI at the mid-season location. Using six months as a basis with twice monthly patrols, a total of 420 flight hours would be required. ISB asserts that this would be sufficient to cover the entire 1992 season (USCG flights included 19 ICERECDET deployments over eight months.) ISB has also proposed patrols in the interior for the LAKI to support the iceberg sighting data base and to identify icebergs crossing 48°N. This would require an additional 360 hours of flight time to cover the area from 52°N twice a month (for six months).

ISB asserts that the locate and identify search strategy will maintain the requirement that there are no unidentified targets outside of the LAKI and less than 10% within 60 nm inside the LAKI. By definition, the search strategy employs a positive identification of identified targets and, consequently, the search strategy should be effective at meeting this requirement. The unanswered question is what happens to the overall POD when this strategy is employed. This strategy with the reliance on visual identification should result in identification at least as good as the existing performance standard. However, if detection does not meet the POD performance standard, then overall identification may not be satisfactory.

Related to surveillance is the ability to deploy the WOCE buoys and AXBT probes. The Dash 7 is capable of deploying the AXBTs and ISB will arrange with DFO to deploy the WOCE buoys. The ISB proposal assumes that the U.S. Coast Guard will continue to procure the WOCE buoys and finance the Service ARGOS data processing.

ISB will employ personnel to provide three ice observers on all surveillance flights. They will use experienced personnel in these positions. The Dash 7 flight crew includes two pilots, one engineer, and one electronics technician in addition to the three ice observers.

The ISB proposal demonstrates that ISB is capable of meeting all performance requirements except for achieving comparable probabilities of detection. The lack of information regarding the locate and identify strategy precludes a determination regarding the adequacy of the POD.

Surveillance costs were generated in $CN and converted to $US using an exchange rate of 1.41. This rate is a recent 18 month high. For planning purposes, an average rate should be used. ISB assumed a six month season which affects the aircraft basing costs. It is not clear from the ISB cost estimates (page 29 in the proposal) whether salaries, hangarage, and depreciation are six month amounts or annual amounts. At some point, it will

be appropriate to compare the ISB costs for the 1992 season with the U.S. Coast Guard costs actually incurred. Note that the 1992 season extended for eight months. In Table 32 below, we assume that the ice observer salaries and the depreciation costs are given as annual amounts and do not need to be adjusted for an eight month season. Aircraft depreciation is assumed to be an annual amount over the expected life of the aircraft. Equipment depreciation is assumed to cover the new FLAR amortized over five years. The interest charge is assumed to be an annual amount. The hangarage charge is assumed to be six months and will be adjusted. It is not clear whether overhead costs are fully covered in the proposal.

For the assumed 420 flight hour level, the adjusted 1992 cost (in 1995 $US) corresponds to a flight hour cost of $4,630 per flight hour. The comparable cost calculation for U.S. Coast Guard surveillance does not include the ice observer cost. It is not clear from the proposal what travel is included in the direct operating costs and whose travel is covered. The travel cost will be retained for comparison with U.S. Coast Guard costs. After eliminating the ice observer cost, the total adjusted surveillance cost is $1,758,000 resulting in a per hour cost of $4,186 per surveillance hour.

Ice Services Branch has submitted a comprehensive proposal with the primary deficiencies being a weak description of the locate and identify search procedure and an incomplete treatment of overhead costs. This lack of information precludes a determination as to whether the proposed surveillance satisfies the performance requirement. The total surveillance cost (adjusted for the length of the 1992 season) is $1,945,000.

4.3.4 National Ice Center Managed Surveillance

The National Ice Center proposal includes two options for surveillance: Option A includes contracted surveillance by the Canadian government and military aircraft; Option B retains the status quo with U.S. Coast Guard HC-130 aircraft conducting iceberg surveillance. NIC has recommended that Option A be pursued (in conjunction with NIC assuming management responsibility for the IIP as discussed below).

In developing its proposal, NIC referred to the different levels of sightings from different sources. NIC noted that their reference did not include the regions in which the sightings occurred and indicated that such locations were an important concern in evaluating sighting input levels. The NIC analysis is driven by costs provided by Atlantic Airways and by the Canadian AES. Specifically, AES can utilize the Atlantic Airways contract with DFO to have the King-Air aircraft available at $1100 per hour (assumed to be $US). AES has quoted a price of $1500 per hour for the Dash 7. (This is a very different cost than the $4,186 per hour computed above based on the ISB proposal.) It is expected that both AES and Atlantic Airways would look for longer term contracts that would include basing costs. For computing total surveillance costs, NIC estimates the required patrol hours at 613, the average total aircraft hours provided by the U.S. Coast Guard in 1992-1994.

The NIC proposal states that "differences between performance characteristics for the HC-130 SLAR/FLAR, Atlantic Airways and DND FLAR, and Dash 7 SLAR have not been clearly identified." The proposal notes that these differences may result in more hours being required or lead to a reconfiguration of Canadian radar systems. The NIC proposal does not explicitly discuss POD, frequency of patrol, and unidentified detections and unclassified detections. NIC notes that the Dash 7 is capable of deploying AXBTs but that alternative means would be required for deploying the WOCE buoys.

NIC identifies the access to National Technical Means data as a potential benefit to NIC's involvement in IIP. This may provide supplemental iceberg detection/identification data. However, this would not be a committed resource and may be preempted by higher priority assignments. It may prove useful if enhanced RADARSAT imagery becomes available. This aspect is identical in Options A and B.

A recurring discussion associated with Option A is the need that NIC has for the U.S. Coast Guard SLAR capability to support other ice reconnaissance missions (e.g., USCG icebreakers in polar regions). The NIC proposal suggests on the one hand that contracting the IIP surveillance to Canada would free additional time for other ice reconnaissance missions. On the other hand, the NIC proposal suggests that failure to retain the IIP surveillance mission may lead to canceling the SLAR digital upgrade and ultimately losing the SLAR capability. NIC emphatically states that it is crucial that the HC-130 SLAR capability be maintained.

The NIC proposal is not clear as to whether the contract price for surveillance aircraft in Option A includes ice observers. The ISB proposal above includes separate salaries for ice observers. The NIC cost proposal includes travel/lodging expenses approximately equal to what would be required if ice observers were deployed from IIP. It is not clear if ice observers were overlooked in preparing the personnel allowance or if ice observers are being provided from other NIC assets. Even if provided by non-Coast Guard personnel, the use of other staff represents an expense that should be charged to IIP.

For Option A, the total estimated surveillance cost is $900,000 and includes $800,000 for 613 contract flight hours (at $1,300 per hour) and $100,000 for travel/lodging. This compares with $4,186 per hour based on Canada's proposal for providing coverage amounting to 420 flight hours.

For Option B, the total estimated surveillance cost is $2,208,500 using estimated element costs that are reasonable. Not included in that cost estimate is air crew travel, aircraft depreciation and the administrative expense charged (30% of operational expense). These costs will raise the total surveillance cost by approximately $930,500 and the new total surveillance cost will be $3,139,000.

The National Ice Center recommended Option A to contract to Canada yields a total surveillance cost of $900,000. The NIC Option B which calls for the U.S. Coast Guard to provide surveillance yields a cost ranging from $2,208,500 to $3,139,000, depending on what cost elements are included. The NIC proposal is weak on implementation details of contracted surveillance. The primary focus was on cost rather than operational effectiveness. The NIC proposal assumed that the system would yield comparable effectiveness or adjustments would be made (in flight hours or equipment) to ensure that performance would be comparable. This is a reasonable assumption given the limited time frame for preparing the proposal.

5.0 ALTERNATIVES AND SYSTEM CONFIGURATIONS

The management, technology and operations alternatives that have been examined and evaluated in this analysis have significant potential interrelationships. The scope of the alternatives is illustrated in Table 33.

The relationships among the alternatives and options are better illustrated in Figure 15.

Table 33 and Figure 15 display the principal areas examined in the COEA and represent decision opportunities for the Program Manager. The key decisions involve management and surveillance functions and the remainder are peripheral to those primary decisions. The costs are summarized in Table 34. (Data sources are included for reference.)

Table 34 must be interpreted with care. The Coast Guard numbers include the 30% administrative services charge on all activities, not just on aircraft costs. The Coast Guard management costs do not include the amortized cost of the ISIS system ($344 K) and the Coast Guard surveillance costs do not include the amortized cost of the SLAR Upgrade ($2.1M).

The COEA is predicated on achieving comparable levels of performance. Both ISB and the NIC have submitted proposals that will provide comparable management performance. With regard to surveillance, the ISB proposed a "locate and identify"

Table 33: Alternatives Summary.

CATEGORY	ALTERNATIVE	OPTION
Management	• Coast Guard • Canada/Ice Services Branch • National Ice Center	• Full Cost Accounting/Admin/Depreciation $4.5M
Technology	• Data Acquisition	• Current System • Airborne Tactical Workstation
	• Data Processing	• Current System • ISIS (OE RCP — $334K)
	• Deterioration Model	• Current System • Improve Classification/Verify Assumption
	• Drift Model	• Current System • Revisit Local Wind Driven Current Model • Improve Classification/Verify Assumption/Data/Retune • Improve Position Estimates
	• Risk Model	• Do Nothing • Simulation Evaluation
Operations	• RADARSAT/GWR	• Do Nothing • Watch Developments
	• Improved CG Surveillance	• FLAR POD • SLAR Dies/FLAR Only • SLAR Upgrade • SLAR/FLAR Sensor Fusion Model
	• Canadian Surveillance	
	• NIC Managed Surveillance	• Canada/Commercial Contract • CG Surveillance

search strategy. It is not clear from the ISB proposal whether that search strategy will achieve the present levels of POD. The Coast Guard should have additional discussions with ISB to clarify the POD question. The NIC proposal had several questions about search procedures and search effectiveness. There was no demonstration of control over the contracted Canadian and Atlantic Airways aircraft for achieving a particular POD. NIC estimated 600 hours and priced the surveillance at quoted rates. As with ISB, it is not clear that the NIC proposal meets the technical performance requirements. Moreover, it is doubtful that the NIC surveillance cost numbers will hold. The price ISB quoted in their proposal and the price that ISB quoted to NIC are significantly different. NIC's offer essentially amount to offering a home to the IIP with the Coast Guard still maintaining primary responsibility. This may be a worthwhile option if the R&D Center relocates in the near future.

The sensitivity analysis of the drift and deterioration models confirmed the need for accurate position estimates of sighted icebergs and radar targets. The addition of GPS to Coast Guard aircraft and the integration of a Tactical Workstation with an upgraded SLAR radar and a FLAR radar will significantly reduce the position uncertainty. In addition, the analysis of the drift model suggested that the model for the local wind driven current needs to be revisited to verify its structure and perhaps to retune it. If Coast Guard surveillance is continued, the SLAR upgrade is a must, paying for itself after 4.5 years by reduced cost of patrol. Similarly, conversion to the ISIS system is a must, providing continued interoperability with Canada and avoiding the development and maintenance of a unique system.

Specific improvements and research requirements are developed in the following section.

6.0 POTENTIAL IMPROVEMENTS AND RESEARCH REQUIREMENTS

The findings in the previous sections clearly identify opportunities for improvement and areas that require further research.

6.1 OPERATIONS/SURVEILLANCE IMPROVEMENTS AND RESEARCH

- Monitor the evaluation of the ERS-1/IPAP experiment to determine its potential for use with RADARSAT.
- Obtain clarification from ISB on "locate and identify" search strategy and determine probability of detection.

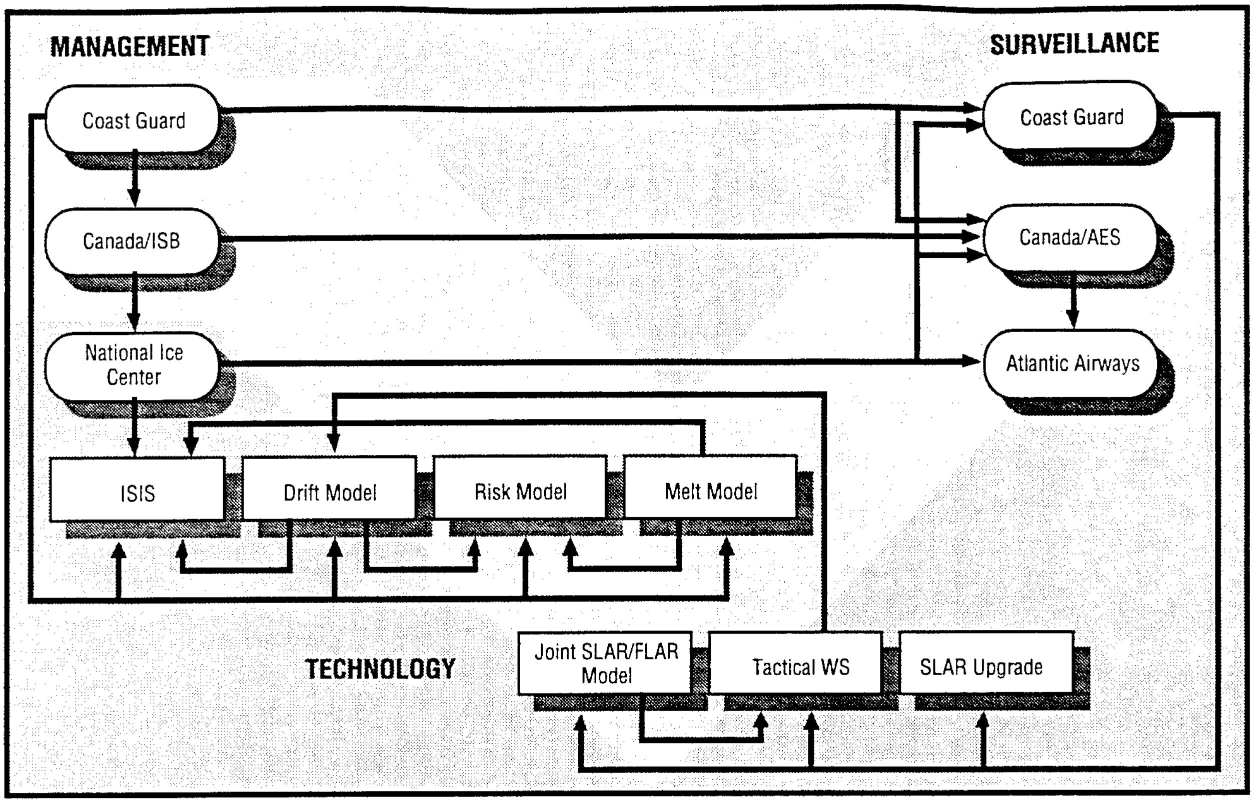

Figure 15: IIP COEA Alternatives Interrelationships.

- Develop experiments to assess the search effectiveness of the AN/APS-137 FLAR radar system.
- Develop an algorithmic approach to optimize the search pattern to maximize the probability of detection by taking advantage of surface wind information.
- Develop an interface for the Airborne Tactical Workstation.
- In anticipation of the delivery of the digital SLAR upgrade, develop an experimental plan to evaluate the "new" system and determine appropriate lateral range curves.
- Develop an experimental plan to examine the synergy between the FLAR and the upgraded SLAR, and develop a multi-sensor fusion model to increase the probability of detection and classification of icebergs.
- Explore the possibility of subcontracting a portion of the surveillance at the beginning of the ice season before the iceberg population grows too large or dispersed.

6.2 TECHNOLOGY IMPROVEMENTS AND RESEARCH

- Revisit the Mooney local wind driven current model and verify discrepancies with other models.

Table 34: Major Alternatives Cost Summary.

Organization	Management	Surveillance
Coast Guard IIP	$1,176,000 (Table 23)	$3,393,222 (Table 6)
Canada/Ice Services Branch	$859,000 (Table 23)	$1,865,000 (Table 32)
National Ice Center	$747,000 (Table 23)	$900,000 (4.3.4)

- Use historical experimental data where possible to confirm present drift and deterioration model parameters
- Conduct a Monte Carlo simulation evaluation of the system model with interactive resights using the integrated risk analysis model to characterize the propagation of uncertainty through the system.
- Integrate the NPGS stochastic drift model being developed by Dr. Alan Washburn with the simulation model to evaluate the potential for improved estimation of the LAKI.

6.3 MANAGEMENT IMPROVEMENTS AND RESEARCH

- Initiate a review with the Department of State to determine what mechanism can be used to credit reimbursements to Coast Guard accounts.
- Initiate discussions with the Department of State to explore alternative mechanisms for collecting cost reimbursements directly from the shipper.
- Use the upcoming triennial review of IIP to develop a plan to increase the number of contributing governments, focusing on those governments with high levels of benefiting tonnage.
- Using the COEA results, conduct a full Mission Analysis to include: definition of the customer, customer assessment (e.g., present INMARSAT FAX survey); establishment of mission performance standards, and an assessment of present and planned operations.
- Review cost allocation procedures to ensure that all costs are properly accounted for on a consistent basis and complete costs are submitted for reimbursement.

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8.0 LIST OF ANNEXES

The detailed analyses that were conducted during the course of this study that formed the basis for the Cost and Operational Effectiveness Analysis presented in this report were structured as stand alone technical reports. The technical reports, identified as Interim Reports Volumes 1-13, are included as Annexes to this Final Report. The titles of the Annexes are self-explanatory.

Annex A: Analysis of Current Operations of the IIP

Annex B: Identification of Alternatives for Phase II COEA

Annex C: Probability of Detection and Classification Using USCG Surveillance

Annex D: Cost Reimbursement for USCG IIP Activities

Annex E: Cost Development for USCG IIP Activities

Annex F: Evaluation of the Canadian and National Ice Center Management and Surveillance Proposals

Annex G: Analysis of the IIP Iceberg Deterioration Model

Annex H: Analysis of the IIP Iceberg Drift Model

Annex I: Survey of Iceberg Sensing by Satellite Imagery

Annex J: Evaluation of Airborne SLAR/FLAR Capability

Annex K: Risk Management Model of IIP Operations

Annex L: Analysis of IIP Data Processing Requirements

Annex M: Review of Sensor Technology and Potential IIP Applications

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APPENDIX 1

INMARSAT IIP USER SURVEY

APPENDIX 1: INMARSAT IIP USER SURVEY

To the Master,

In 1992, over 145 million GRT of shipping transited the North Atlantic shipping lanes during the International Ice Patrol (IIP) season. During the ice season, the IIP publishes twice daily ice bulletins and a daily ice chart available on facsimile. As part of an on-going effectiveness study of the International Ice Patrol, we are very interested in finding out how you value the IIP's information and how you may use it to plan your routes. We would appreciate it if you would complete the few questions below and return the survey to IIP.

Please mark an X in the block that best describes your opinion or use of the IIP information.

When you are operating in the IIP area (40N-52N,39W-57W):	ALWAYS	USUALLY	SOMETIMES	NEVER	DON'T KNOW
1. Do you receive the IIP SAFETYNET BULLETIN at least once a day?					
2. Do you receive the IIP SITOR BULLETIN at least once a day?					
3. Do you receive the IIP NAVTEX BULLETIN at least once a day?					
4. Do you receive the IIP HF FACSIMILE CHART every day?					
5. Do you record the Limits of All Known Ice from voice broadcasts?					
6. Do you keep the Bulletin or Ice Chart available in the pilot house?					
7. Do you plot the Limits of All Known Ice on your navigation chart?					
8. Do you plot the location of icebergs on your navigation charts?					
9. Do you change your course on a regular basis to pass outside the Limits of All Known Ice?					
10. Does your course take you inside the Limits of All Known Ice?					
11. Do you report iceberg sightings to the IIP?					
12. Do you make weather reports with sea surface temperatures in the IIP area?					

13. How valuable are the IIP products?
    - ❑ Very valuable and important ❑ Somewhat valuable ❑ Not valuable
14. Please rank the importance of the IIP products (1=most important, 4=least)
    - ❑ Ice Bulletin ❑ NAVTEX Broadcast ❑ HF-Facsimile Ice Chart ❑ Voice broadcast
15. How many transits do you make through the IIP area each year during March through September?_____
16. Please indicate the type of vessel that you usually operate.
    - ❑ Oil tanker ❑ Other tanker ❑ General cargo
    - ❑ Container ❑ Fishing ❑ Passenger
    - ❑ Other______________________
17. Compared to conditions when there are no icebergs and IIP is not in operation, please estimate the number of extra hours of enroute time that are required on an average transit to avoid icebergs or to remain outside the Limit of All Known Ice:_______
18. Based on your experience, how accurate is the Limit of All Known Ice?
    - ❑ Extremely accurate (icebergs never seen outside the Limit of All Known Ice)
    - ❑ Very accurate (icebergs ocassionally seen outside the Limit of All Known Ice)
    - ❑ Somewhat accurate (icebergs usually seen outside the Limit of All Known Ice)
    - ❑ Never accurate (icebergs always seen outside the Limit of All Known Ice)
19. Comments:

Thank you for your help in evaluating the IIP services. Please fax the completed form to IIP at (203) 441-2773 or mail it to:

International Ice Patrol,
1082 Shennecosset Rd, Groton, CT 06340 USA

APPENDIX 2
INSURANCE AND USER IMPACTS

APPENDIX 2: INSURANCE AND USER IMPACTS

This Appendix contains a number of supporting documents regarding insurance issues and user impacts related to the IIP.

M. Shelly facsimile of 10/12/99
D. St. Pierre e-mail of 10/12/94
D. St. Pierre e-mail of 10/28/94
D. Rail (Ocean Routes) letter of 9/21/94

FRANK BARBER AND OTHERS
UNDERWRITERS AT LLOYD'S

Telephone: Office 071 283 0045
Box 071 327 3130

Facsimile No: 071 623 8233
071 623 2005

10-13 Lovat Lane
London
EC3R 8DT

FACSIMILE MESSAGE

From: MR. M. J. SHELLY

Date: 10 . 12 1993

Total No. Pages: 1

To: CLARK PRITCHETT

Fax No: 0101 203 441 2773

Company: USCG R & D CENTER

Subject:

DEAR SIR,

WE INSURE NUMEROUS AMERICAN, CANADIAN AND EUROPEAN YACHTS, WE WOULD NOT INSURE CRAFT CROSSING THE ATLANTIC ON A NORTHERLY ROUTE BETWEEN NOVEMBER AND MARCH.

SOME LARGE CRAFT GO FROM EUROPE TO FLORIDA &/OR WEST INDIES AND VICE VERSA UNDER THEIR OWN POWER OR 'DOCK EXPRESS' AT THIS TIME BUT ONLY ON A SOUTHERLY ROUTE SAY MADEIRA, CANARY ISLANDS AND CAPE VERDE.

REGARDS

MICHAEL SHELLY

Date: Oct 12, 1994 11:59 AM Message ID: 199410121137
From: DSTPIERRE%ONREUR.decnet@onreur.navy.mil/cgsmtp
To: "C.Pritchett/RDC02" <C.Pritchett/RDC02@cgsmtp.comdt.uscg.mil>
Copies: "NIO-3/G-NIO" <NIO-3/G-NIO@cgsmtp.comdt.uscg.mil>
Attach:
Subject: Re[2]: Icebergs and Lloyds of London ...

Larry,

Just a brief update.

I have weeded through 20 or so LLyod's related activities and am currently engaged with a Mr. John Moloney, General Secretary of LLoyd's Underwriters Association who is ACTIVELY trying to find the department/individuals within the LLoyd's octopus of associated companies that utilize the product services of the International Ice Patrol. Mr. Moloney has just called to say he is still working on it but has been hampered by the absence (on travel) of some key individuals who are expected to return by the end of the week.

So, bottom line is that I have someone "inside" LLoyd's working on it but it will take a little while. Frankly, I and Mr. Moloney were both surprised at the difficulty of the task. He told me the "original Titanic contract" stands framed on displayed in their HQ but he has had difficulty in finding anyone within his own organization who is currently concerned with icebergs!

"Those who fail to learn the lessons of the past are condemned...etc."

Cheers from London,
David

Date: Oct 28, 1994 3:33 PM Message ID: 199410281444
From: DSTPIERRE%ONREUR.decnet@onreur.navy.mil/cgsmtp
To: "C.Pritchett/RDC02" <C.Pritchett/RDC02@cgsmtp.comdt.uscg.mil>
Copies: "NIO-3/G-NIO" <NIO-3/G-NIO@cgsmtp.comdt.uscg.mil>
Attach:
ubject: Re[3]: Icebergs and Lloyds of London ...

Larry,

Stand by for some surprising information.

Apparently, NO ONE at LLoyds or its affiliate use or monitor the IIP Iceberg Warning Products!

John Moloney, General Secretary of LLoyds Underwriters Association, (tel:+44-71-626-9420) has canvassed all the affiliated LLoyd's activities and has found no one who uses or monitors the IIP services. He has assured me that he has personally talked to the heads of the 20 or so activities that form the umbrella called "LLoyds of London" and asked them to canvass each of their activities internally.

Moloney reported back to me this morning stating the above.

He, however, did add that he found one organization interested in receiving such products. Mr. David Cotton, Manager of the LLoyds affiliated SALVAGE ASSOCIATION (tel:+44-71-623-1299), indicated to Mr. Moloney that The SALVAGE ASSOCIATION would be interested in receiving such products. This is a lead for your sales folks! (Buy your Coast Guard Products here! Two for the price of one on Thursdays, Early Bird specials available!,etc.)

rry, I can surmise many reasons why LLoyds fallen away from such apparently important services. Among them: the advent of radar, the writing of policies that dictate that the ship (not LLoyds) is responsible for monitoring all warnings (failing to do so voids the policy), etc.

If I can help you more, let me know. However, based on my conversations with Mr. Moloney, I believe the ship OWNERS not the ship INSURERS are your target.

Cheers from London,
David

WNI oceanroutes

21 September 1994

Clark Pritchett
USCG R&D Center
Groton, Ct. 06340-6096

Dear Clark,

I enjoyed our phone conversation on 20 September regarding the use of the International Ice Patrol bulletins.

At WNI Oceanroutes, we use the bulletins daily to advise the latest ice limits to the vessels using our service in the north Atlantic ocean. We estimate that we pass the ice information to 1200-1500 ships per year. If the ice information was not available, we would have to rely on climatological information and random reports from ships passing near the ice. This would force us to recommend more conservative routes to the vessels using our service. It is estimated the additional distance and sailing time associated with the more conservative routing would cost our clients 3-4 million dollars or about 2500 dollars per voyage. In addition, the risk of the vessels encountering unexpected ice would be much greater.

I have included the requested brochures. However, the brochures do not reflect the merger between Oceanroutes and Weathernews. Our new name is now WNI Oceanroutes.

Please let me know if you have any further questions.

Sincerely,

Dave Rail

Dave Rail
Customer Service Manager

WEATHERNEWS INC
680 West Maude Avenue, Suite 3
Sunnyvale CA 94086-3518

TEL 408-245-3600
FAX 408-245-5787